1981 C.B. ANNUAL REPORT

VOLUME 2

ENVIRONMENTAL ANALYSIS

CATHEDRAL BLUFFS SHALE OIL COMPANY

751 HORIZON COURT

GRAND JUNCTION, COLORADO 81501

APRIL 30, 1982

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April 30, 1982

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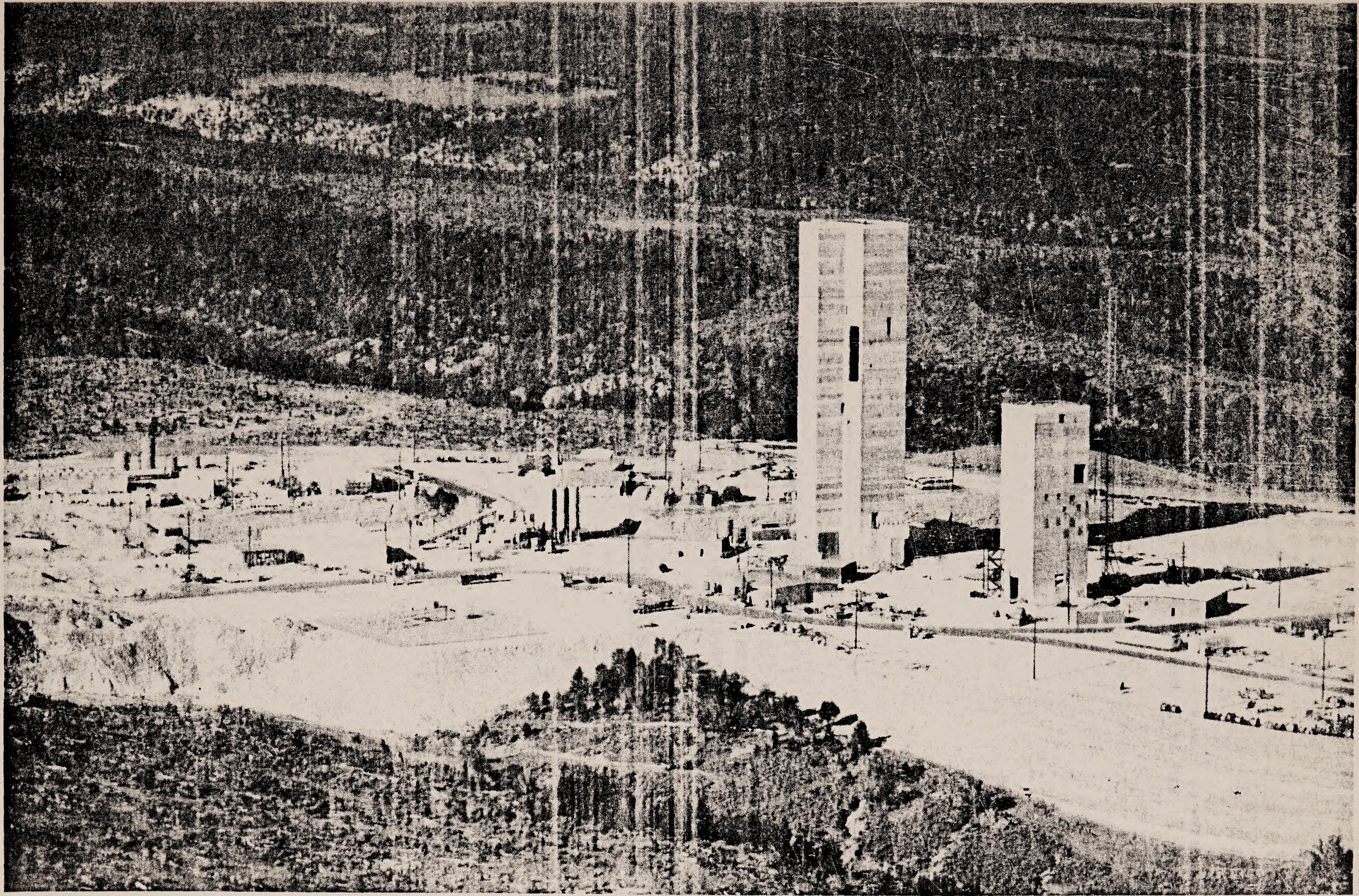

FOREWORD

The 1981 C.B. ANNUAL REPORT is submitted to fulfill the requirements of Oil Shale Lease Number C-20341 as stated in Section 16(b) of the Lease, Section 1.(C)(4) of the Lease Environmental Stipulations, and Condition of Approval (No. 3) of the Detailed Development Plan issued on August 30, 1977. This report consists of the following volumes:

Volume 1 - Summary of Development Activities, Costs and Environmental Monitoring

Volume 2 - Environmental Analysis

Volume 2A - Volume 2 Supporting Data

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1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

The Environmental Baseline Period for Oil Shale Tract C-b covered the period from November 1, 1974, to October 31, 1976. Results have been reported in nine Quarterly Data Reports, eight Quarterly Summary Reports, C-b Annual Summary and Trends Report (1976), and a five-volume Environmental Baseline Program Final Report (1977), all submitted to the Oil Shale Supervisor.

From November 1, 1976 through August 31, 1977, the C-b Tract was under a period of suspension of the Federal Oil Shale Lease. The monitoring conducted during this period was executed under a program known as the Interim Monitoring Phase. Environmental data for this time period were submitted to the Oil Shale Office (OSO) on October 14, 1977 (Interim Monitoring Report #1). The Interim Monitoring Period was later extended by the OSO to cover the period from September 1, 1977 through March 31, 1978. Data for this time period were submitted to the OSO on May 15, 1978 (Interim Monitoring Report #2). The Development Monitoring Program was initiated in April 1978. The Development Monitoring Program for Oil Shale Tract C-b was submitted to the OSO in a document dated February 23, 1979 and approved by the OSO on April 13, 1979 subject to thirteen Conditions of Approval contained in the approval letter. Semiannual environmental data reports are submitted every January 15 and July 15.

The Interim Monitoring and Development Monitoring Programs have been reduced and changed from the Environmental Baseline Monitoring Program in many areas. Therefore, emphasis is now placed on key indicators of environmental quality and/or change. The 1981 C.B. Annual Report, Volume 2 provides detailed data analysis.

The purpose of Volume 2 of this report is to fulfill the requirement of the lease to provide the Oil Shale Supervisor's Office with an annual report of environmental analyses. The Development Monitoring Plan states the following objectives with respect to environmental monitoring:

> The purposes or objectives of environmental monitoring as defined in Section 1 (C) of the Stipulations are to provide: (1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data, (2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State and local environmental protection and pollution control requirements, (3) timely notice of detrimental effects and conditions requiring correction, and (4) factual basis for revision or amendment of the Stipulations.

The approach taken in the Development Monitoring Program uses conceptual model shown on Figure 1.1-1. The "outputs" or actions constitute the Development Monitoring Plan and its implementation (findings) as a result of monitoring (Box 4). "Inputs" consist of the environmental data base, the Lease Environmental Stipulations, the details of Tract operation, and applicable local, state, and federal regulations (Box 1). The mid-component or "decision matrix" (Box 2) consists of the three major criteria to which

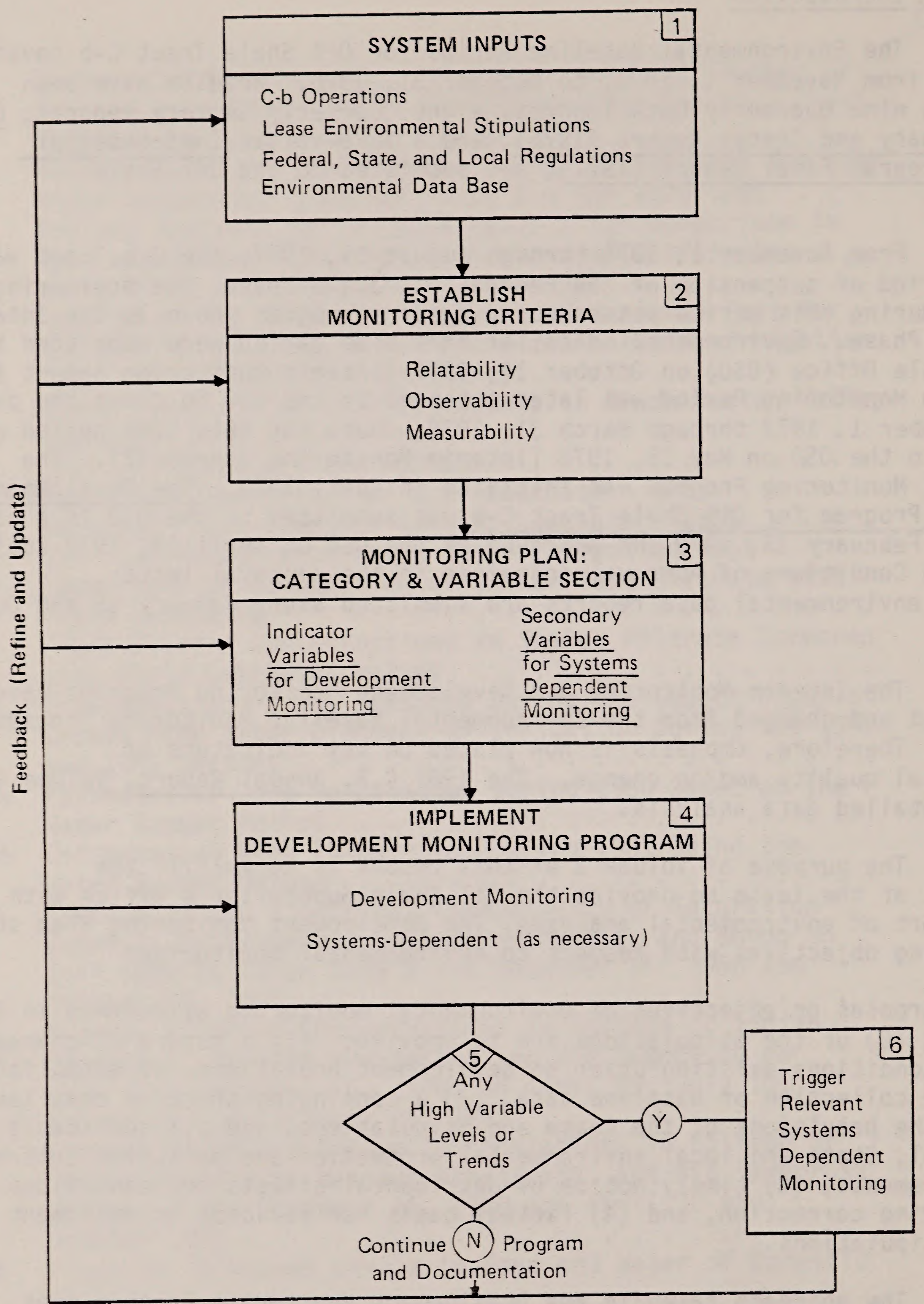


Figure 1.1-1
Conceptual Approach to Development Monitoring

candidate variables for monitoring are subjected (relatability, observability, and measurability). The selected variables in the Program which are "screened" by these criteria become known as indicator variables. A significant feature of this conceptual model is its feedback capability. That is, variable levels are assessed against "expected" levels (Box 5). In the event that high levels are obtained, a "systems dependent" mode of either more intensive monitoring, use of additional stations, or added variables (or all three) is triggered in Box 6. Feedback from the program results to date to obtain improved inputs ensures continual review and refinement of the monitoring programs as additional information is collected and analyzed. This is a provision not only for the evolution of the monitoring program in terms of methods used in collecting and analyzing data and for refining sampling frequencies and locations, but also a provision for factoring in the phases of development and their subsequent effects on the system.

Volume 2 documents the analyses and conclusions relative to assessment of potential environmental impacts and trends that may be indicated by the collected data. Since development activities were not started until 1978, much of the data and analyses may be considered as a continuation of environmental baseline and background definition.

1.2 Summary

Environmental monitoring and analyses are continuing on Tract C-b. Development activities commenced within the past four years have resulted in increased activity on the Tract in the form of off-road vehicular use, facility construction, shaft sinking and outfitting associated headframes, and traffic into and out of the area. All activity has been conducted within strict adherence to environmental, permit, and lease regulations. Environmental impacts, where they exist, have been confined to the immediate Tract and within limits defined in the Detailed Development Plan.

1.2.1 Indicator Variables

The Development Monitoring Program has been brought into sharper focus with the identification of Class 1 indicator variables. These are key environmental variables collected at representative stations in at least monthly sampling frequency. Time series plots, generated by the computer from the data base and all to a common time scale, are updated in the semiannual data reports to provide visual analyses of trends and interrelationships. As a statistical screening process, linear short- and long-term trends have been examined at a five percent level of significance for air and water and to 20 percent for biology; results are discussed in the respective chapters.

1.2.2 Tract Imagery

A photographic record of Tract changes has been continued through 1981 as in previous years. A 360° horizontal pan is photographed in color on a yearly basis at 35 photo points. Color infrared panoramic photographs of the vegetation around springs and seeps were obtained three times during the growing season.

Landsat digital imagery was used as in previous years to monitor vegetative condition in the Tract vicinity. Extensive cloud cover throughout every Landsat pass during the peak growing season precluded new data in 1981.

1.2.3 Hydrology

A development monitoring program has been implemented to provide water quantity and quality data for the purpose of impact evaluation. Streams, springs, seeps, alluvial and bedrock aquifers, shafts and impoundments are presently monitored.

Baseline studies indicated the mean flow for the reach of Piceance Creek adjacent to the Tract to be approximately 13 cfs. Records since then indicate no significant change in mean annual flows; that for 1981 was 7 cfs (Station WU07). One-day minimum flows there have been as low as 1 cfs. Maximum of the mean daily flows upstream and downstream of the Tract for water year 1981 were:

	Upstream (Station WU07)	Downstream (Station WU61)
Previous Maximum of the Mean Daily Flow (cfs)	157 (May, 1979)	149 (May, 1979)
1981 Maximum of the Mean Daily Flow (cfs)	19	34

No significant trends in streamflow are apparent.

The flow of groundwaters are governed by the stratigraphy of the Tract. The arrangement of aquifers and aquicludes (or aquitards) employ the terms UPC1, UPC2, LPC3 and LPC4, representing in descending order four aquifer identifications in the Upper Parachute Creek and Lower Parachute Creek Formations. This conceptual model was derived in 1978 from the two exploratory core holes that preceded the sinking of the V/E Shaft and the Service and Production Shafts and reinforced by shaft-sinking results. Water producing and nonproducing zones were identified by pump-spinner tests run in the core holes. From the pump-spinner tests, the Four Senators zone was considered an aquiclude or aquitard between UPC1 and UPC2. The Mahogany Zone which has for many years been considered an aquiclude or an aquitard, showed water production in its lower part during the pump-spinner tests. Therefore, only the upper 25 feet of the Mahogany Zone was considered in this model as a barrier between UPC2 and LPC3. The lowest of the four aquifer units, LPC4, includes most of the R-5 and L-4 zones (U. S. Geological Survey System). No boundary was designated to separate the Uinta from UPC1. Mining will occur in the Mahogany Zone. A well recompletion program was conducted in 1980 and finished in December of that year. Its purpose was to both narrow the monitoring well (depth) interval in each discrete well string and to provide better overall coverage of monitoring per the four aquifer concept described above. Well level time histories are examined only after the recompletion date.

Dewatering of the shafts continued in 1981; however, operations were temporarily suspended on the V/E Shaft and it was allowed to flood beginning in September. As explained in Section 7.2, Water Management the three methods used to dispose of excess mine water were direct discharge, sprinkler irrigation (land application) in above-freezing periods, and the

preferred method of reinjection into groundwater zones of like water quality. Table 7-1 of Volume 1 summarizes water amounts treated by the three methods. Reinjection was initiated in 1981. Drawdown characteristics that the wells exhibited in 1980 were now replaced by characteristic curves caused by the reinjection test.

Data collected during the past two years suggest that the tight confining zones of oil shale may restrict the vertical movement of groundwater between the major hydrologic units. Significant data in this regard came from two well pairs along Piceance Creek north of the Tract. Each well pair consists of a deep bedrock well and a nearby alluvial well. Monitoring of well pairs is designed to determine whether the dewatering activities in the deep bedrock aquifers are affecting the alluvial aquifers. As shown in Figures 9-8 and 9-9, the depressurizing effects which have been detected and measured in the deep bedrock wells have not been observed to date in the alluvial companions, providing strong evidence that they are not hydrologically connected.

Extensive work has been accomplished by C.B. and its consultants regarding increased understanding of the hydrology of the Piceance Basin. This may be summarized by a set of working hypotheses which we hold to be true in view of this extensive work; they are undergoing further scrutiny as further results of the monitoring program become available. These are: 1) lateral or infraformational migration of groundwater may be extremely slow; 2) given the range of Darcy velocity values that exist at C.B., the maximum time for water travel across the Piceance Basin within the deep bedrock aquifers of the Green River Formation might be measured in thousands of years or even longer; 3) except all along fault zones, vertical leakage across the stratigraphic units in the Green River Formation may be insignificant; 4) the leached zone may represent results an ancient event; 5) some upward leakage may occur from the deep aquifers to the shallow formations in the stream bottoms in the northern part of the basin; this leakage is likely controlled by major faults; 6) most of the springs may be from very shallow sources; 7) the Uinta Formation may contain both unconfined and confined groundwater in the C.B. area, and may be responsible for much of the recharge to Piceance Creek and its tributaries; 8) that the potentiometric contours bend around Piceance Creek is not necessarily due to upward leakage from the bedrock aquifers; 9) the deep bedrock aquifers in the Piceance Basin may have experienced relatively little flushing since the end of Uinta time; 10) of the recharge that does occur to the deep bedrock, a significant proportion may enter the upturned Green River Beds along the eastern rim of the Basin; 11) at the C-b Tract, vertical leakage if it occurs as a result of mining, would be downward; 12) from the mining zone at the C-b Tract, lateral migration, if it occurs, should have no effect on quantity and quality of the usable groundwater.

Water quality data for stations upstream and downstream from the Tract on Piceance Creek, and for stations in Stewart and Scandard Gulches are summarized in Section 5.3. During 1981 discharges to Little Gardenhire Gulch were made primarily early in the year under the NPDES permit and Station WU42 measured water quality affected by these discharges. All discharges in 1981 contained the high fluoride levels characteristic of the lower aquifer zones; when diluted with Piceance Creek waters the fluoride maximum value was 4.8 mg/l. On an annual average basis fluoride has increased (Station WU61) from 0.8 to 2.2.

For both springs and alluvial wells there are no significant long-term trends in water quality values for any of the major constituents. Those examined for trends were temperature, pH, conductivity, DOC, arsenic, fluoride, boron, TDS, molybdenum, sodium, sulfate, and ammonia.

1.2.4 Aquatic Ecology

Benthos and periphyton sampling was done in 1981 as in previous years. Irrigation, cattle grazing, springs, and Tract C-b water discharge may affect Piceance Creek aquatic systems. While the 1981 study showed no large changes in the benthic fauna of Piceance Creek, macroinvertebrate data do show an increase in relative abundance of the Oligochaeta at the two downstream stations with respect to the control (Stewart) station. Comparisons to previous studies, including the baseline conditions, appear to rule out Tract C-b discharge as being a major reason for this difference. The changes observed seem to be attributable primarily to agricultural impacts and natural variations; the identical conclusion is derived for periphyton.

1.2.5 Air Quality

Section 6-0 discusses the air quality monitoring network; Station AB26 came on line in October, as a pristine or control site under prevailing winds inasmuch as AB23 has been impacted (primarily particulates from site construction).

Compliance with Federal and State air quality standards continued to be maintained on the C-b Tract during 1981 as indicated in Section 6.0. Data for the most recent three year period are shown.

Possible linear trends in air quality variables over time have been examined for the 1981 time period and since baseline and are summarized in Section 6.0. Negative long-term trends continue to exist for carbon monoxide probably due to the higher readings exhibited in baseline and shortly thereafter provided by the inaccurate instrument used at the time.

Visual range measurements at the Tract have exhibited essentially no change since 1975.

1.2.6 Meteorology

Figures 9-11a and 9-11b show the climatological network. Meteorological data collected in 1981 are generally consistent with those of prior years. Peak precipitation events compare as follows (cm):

	1979-1980	1980-1981
1-hour	1.1	1.1
24-hour	2.0	2.1
Month	6.6	10.1

1.2.7 Noise

Environmental noise has increased over baseline due to Tract activities. Peak values of approximately 80 dBA were reached during

1981, a value equal to the State noise standard for an industrial zone. The Tract is not classified as industrial, however.

1.2.8 Wildlife Biology

Section 8 discusses the biological network also showing areas of the sprinkler (land application) system. Sampling protocol and locations are discussed in Section 8.

Deer pellet group densities were lower in 1980-1981 than in 1979-1980. Development activities have not significantly affected pellet group densities. Relatively heavy deer losses in 1980-1981 were due to the severe winter.

Bitterbrush utilization was higher in 1980-1981 than the previous year (72% vs. 61%). Browse utilization was not significantly affected by development activities.

Highest deer road count in 1980-1981 was 494 in April. Migrational distribution was not significantly affected by C-b.

Seventy percent reduction in deer road kills were noted in 1980-1981 compared to 1979-1980, probably attributable to mild winter and reduced deer population in 1980-1981. Deer herd size appears to exert more influence on road kill than vehicular traffic.

Regarding natural mortality only 16 deer carcasses were found in 1981 compared to 60 in 1980 probably due to the milder 1980-1981 weather.

Wintering deer in the Tract area appear to be using the habitat much as they did during the pre-development period.

Coyotes and lagomorphs are the two medium-sized mammals monitored on Tract. Coyotes are of ecological significance because they are a major predator on Tract C-b. The index of abundance of 40 was the lowest obtained over the past six years. No significant changes in abundance of lagomorphs were detected over the past two years.

Small mammals trapped included deer mice and least chipmunks. In 1980 it appeared that deer mice and least chipmunks avoided the sprinkler-irrigated areas and golden-mantled ground squirrels were attracted to them; in 1981 no such attraction or avoidance was concluded.

Development activities have not caused any significant changes in songbird diversity or density. Mourning dove population continues to fluctuate yearly without any definable patterns. Development activities seem to have little effect on raptor activity in the area.

1.2.9 Vegetation

There have been no major changes in the herb layer species composition over the last seven years. There has been a trend showing a de-

crease in total plant cover. This may be related to changes in cover estimation or, it may be related to the successional dynamics of the chained rangelands. Shrub species composition has not changed, however total shrub cover and density have increased. None of the noted changes in the vegetation appear to be related to the development of the site.

Patterns of herbaceous production are essentially the same as observed during all previous years. Utilization in 1981 was greater than any previous year, probably related to a longer period of spring grazing on Tract. Irrigation rate, fertilization rate, and application frequency can all cause significant differences in herbaceous production.

No threatened or endangered species of plants or animals were observed on Tract.

Revegetation success of the topsoil piles has been achieved regarding herbaceous cover, diversity and productivity.

1.2.10 Ecosystem Interrelationships

Ecosystem interrelationship studies have been continued as a means of assessing the potential impact of environmental perturbations resulting from development activity. Quantitative studies to date include the effects of climatic variations on herbaceous productivity and effects of traffic, climate, and size of mule-deer herd on deer road-kill. Previously established linear results that still hold are as follows: (1) herbaceous productivity correlated best with precipitation in April-May-June and total precipitation of the previous year; and (2) deer road-kill correlated best with deer road-count.

1.2.11 Items of Aesthetic, Historic, or Scientific Interest

Surface activity was somewhat limited at the site in 1981 as in 1980. A concerted effort has been made to paint and locate new structures to reduce any aesthetic impact. Additionally, the on-site environmental staff has thoroughly investigated every site of disturbance and no additional historic or scientific discoveries have been made.

1.2.12 Health and Safety

Accident frequency analyses and inspection reports (Mine Safety and Health Administration and Colorado Division of Mines) are included in the Development Monitoring Plan and its reports. At C-b based on 956,636 man-hours, there were 22 lost-time accidents. The site injury (incident) rate in 1981 was 7.53 (reportable accidents/200,000 man-hours). This compared with 15 lost-time accidents in 1980, and an injury rate of 5.10.

1.2.13 Toxicology

This year there was only one series of toxicological tests conducted by Cathedral Bluffs. This series of screening tests was performed by Applied Biological Sciences Laboratory of Glendale, California under the direction of Dr. Paul Nees (HCC) and Mr. Tom Samson (OOSI). The four Lurgi Retort materials that were tested were: light oil (LGT-21), middle oil (LGT-5),

heavy oil (LGT-4), and process water (LGT-12). The following four tests were run on each sample: acute oral, acute dermal, primary skin irritation, and eye irritation. The results of this testing are shown in Table 1.2.13-1 Lurgi Retort Toxicological Test Results.

Also during 1981 the finalized toxicological testing program for Logan Wash Retorts 7 and 8 was prepared.

1.2.14 Data Management and Quality Assurance

All air, water and microclimate data are currently in a computerized data base called RAMIS. Biological data are partly in manual data bases, as documented in data reports to the OSO and partly in RAMIS.

Data tapes for air quality and meteorology have been furnished to the OSO for data through November, 1981.

Quality assurance (QA) documents for air and water were prepared in 1981 and procedures were implemented in the field programs. Two air quality audits were conducted in 1981.

1.2.15 Reporting

Annual reports are submitted during the anniversary month of the Lease (April). Semiannual data reports are submitted to the OSO on January 15 and July 15. Air quality data volumes in these reports are also submitted to EPA, Region VIII, and the Air Quality Control Division of the Colorado Department of Health.

TABLE 1.2.13-1

Lurgi Retort Toxicological Test Results

	Acute Oral	Acute Dermal	Primary Skin Irritation	Eye Irritation
Light Oil (LGT-21)	Relatively Non-Toxic	Non-Toxic	Slight Irritant	Non-Irritating
Middle Oil (LGT-5)	Slightly Toxic	Non-Toxic	Moderate Irritant	Non-Irritating
Heavy Oil (LGT-4)	Relatively Non-Toxic	Non-Toxic	Moderate Irritant	Non-Irritating
Process Water (LGT-12)	Non-Toxic	Non-Toxic	Non-Irritant	Non-Irritating

2.0 TRACT DEVELOPMENT SCHEDULE AND MAPS

2.1 Development Schedule

The "Milestone" schedule as approved by the OSO and the near-term update of projected activities are presented as Figure 3-1 and Figure 3-3 respectively in Volume 1 of this report. A comparison of proposed vs. actual schedules for calendar years 1980 through 1982 is presented in Figure 3-4 of Volume 1.

2.2 Maps

Three fold-out charts (Exhibits A, B and C) depicting the monitoring site locations for development monitoring are included in the jacket inside the back cover of this volume. Exhibit A is a map of the Piceance Basin giving key features of the hydrologic monitoring program. Exhibit B is a list of stations of the hydrologic monitoring program illustrated in Exhibit A. Exhibit C is a map of the development monitoring activities at the site. Monitoring locations are shown as four-digit computer codes on the map; comparisons of computer codes and "conventional" site locations are included in Appendix Table A2.2-2. Another useful map in the jacket of Volume 1 includes:

1:7200 Topographic Map of the Tract.

3.0 INDICATOR VARIABLES

3.1 Introduction and Scope

Examination of the number of sampling stations multiplied by the number of variables sampled multiplied by number of samples taken in a year's time leads one to the correct conclusion that an astronomical amount of data is being collected. Indeed the central problem of this entire volume is to provide the means to detect trends in the least number of variables that can provide a true perspective of environmental change.

This chapter attempts to initiate the solution to this problem by the use of indicator variables. Indicator variables are those monitored, environmental parameters that can be expected to provide the earliest clues of potential change from the baseline environment. This chapter identifies the indicator variables selected for environmental disciplines of hydrology, air quality and meteorology, noise, and biology. Site locations are shown on the jacket map.

3.2 Nomenclature

Action Level	Magnitude of an indicator variable or its trend which triggers systems dependent monitoring.
Class I Indicator Variables	Those sampled at least monthly.
Class II Indicator Variables	Those sampled less frequently than monthly.
Indicator Variable	Those measured environmental variables selected for monitoring because they are expected to provide earliest clues of potential change from the baseline environment.
Linear Trend	Linear variation over time or linear fit to the trend.
Measured	Sampled via field measurement.
Reporting Interval	Most frequent tabulation interval (over time) in the data base.
Trend	Variation over time.
Variable	A quantity capable of assuming any of a set of values.

3.3 Role in Effects Assessment

These variables are: (1) most sensitive to change in quality; (2) indicators of natural or climatic change; and (3) subject to Federal and State standards because of concern for human health and public welfare.

Via early data reduction and analysis, changes or adverse time-trends in the observations can be flagged in timely fashion. Visibility is provided by maintaining current time-series plots of the key variables. Impact of development activity is also assessed through statistical comparison of data collected on both development and control sites. If trends and differences signal adverse environmental impact, additional and increased monitoring will be triggered. (Referred to as Systems Dependent Monitoring.)

3.4 Identification of Class I Indicator Variables

Indicator variables are that subset of the environmental parameters that best indicate the "state" of the ecosystem. However, the combinations of monitored indicator variables and collection stations exceed 1000. Therefore, Class I Indicator Variables have been identified in order to further reduce the number of parameter and site combinations to a realistic quantity for the purpose of close observation and more detailed analysis. Class I Indicator Variables are key environmental variables collected at representative stations on at least monthly frequency. This frequency-distinction is entirely arbitrary; the significance is in the fact that time series plots are maintained and updated semiannually only for all Class I Indicator Variables.

This chapter identifies only the Class I Indicator Variables; however, all monitored variables are included in the data reports.

3.4.1 Tract Imagery

Tract imagery is carried out annually under both a surface and an aerial program. The aerial program over the last two years consisted of historical and present use of Landsat digital data. Black and white aerial photography is planned every three years. No Class I Indicator Variables associated with tract imagery are identified at present.

3.4.2 Hydrology and Water Quality

Class I Indicator Variables for hydrology are identified in Table 3.4.2-1. Parameters are collected either daily or monthly as indicated by the codes in the table.

3.4.3 Air Quality and Meteorology

Class I Indicator Variables and stations for air quality and meteorology are identified in Table 3.4.3-1. Collection frequency for those parameters coded with D is continuous; hourly averages are reported in the data reports. Daily averages and peaks calculated from the hourly averages are used in the time-series plots for these variables. Daily totals are plotted for those parameters coded with a T.

TABLE 3.4.2-1

Hydrology Class 1 Indicator Variables

	Major U.S.G.S.				Springs and Seeps				Alluvial Wells				
	WU07	WU61	WU58	WU22	WS01	WS03	WS06	WS07	WA03	WA05	WA06	WA08	Deep Wells
Ammonia	M	M	M	M									
Boron	M	M	M	M									
Fluoride	M	M	M	M									
Total Dissolved Solids	M	M	M	M									
Arsenic	M	M	M	M									
Sediment	M	M	M	M									
Precipitation			M	M									
pH	D	D	D	D	M	M	M	M	M	M	M	M	
Temperature	D	D	D	D	M	M	M	M	M	M	M	M	
Flow	See Note 2				See Note 3								
Conductivity	D	D	D	D	M	M	M	M	M	M	M	M	
Dissolved Oxygen	D	D	D	D	M	M	M	M					
Level									See Note 4				M

NOTES: 1) Frequency of data sampling is coded: D for daily average of continuous sampling; M for monthly samples. Precipitation measurements are not taken at stations WU07 or WU61.

2) Daily at four major stations, monthly at all others.

3) Weekly - all stations.

4) Monthly - all stations.

TABLE 3.4.3-1

Air Quality and Meteorology Class 1 Indicator Variables

	Sampling Stations							
Variable	AB20	AA23	AB23	AB26	AC20	AD42	AD56	AREA
SO_2	D		D	D				
H_2S	D		D	D				
O_3	D		D	D				
NO_x	D		D	D				
NO_2	D		D	D				
CO	D		D	D				
Particulates (every 3rd day)	T		T	T			T	
WS - 10m	D	D		D		D	D	
WD - 10m	D	D		D		D	D	
WS - 30m		D						
WD - 30m		D						
RH			D	D				
Temp - 10m	D		D	D		D	D	
Pressure			D					
Solar Radiation			T					
ΔTemp - (60m - 10m)		D						
Precipitation	T		T	T				
Evaporation			T					
Inv Ht					D			
Visual Range (every 6th day in spring and fall)								VR

NOTES: Frequency of sampling is continuous for all variables except visual range. Evaporation measurements are confined to the growing season. Daily averages with min and max hourly values are plotted for those variables coded with D. Daily totals are plotted for those coded with T.

3.4.4 Noise

Noise is measured at two stations in decibels. Class I Indicator Variables, shown in Table 3.4.4-1, are peak measurements of noise level for daytime (0700 through 1900 hours) and for nighttime (1900 through 0700 hours).

3.4.5 Biology

Much of the biological data collection is accomplished seasonally or annually. These data and analyses are important indicators of possible oil shale development environmental impacts. However, under the definition of Class I Indicator Variables, a much smaller set of biological environmental parameters are identified. These parameters and their collection frequencies are shown in Table 3.4.5-1. The collection frequency of microclimate data is twice monthly and is indicated by 2M in this table. Monthly and weekly collection frequencies are shown in the table with M and W, respectively.

3.5 Action Levels

An action level is that magnitude of an indicator variable or its trend which triggers systems dependent monitoring.

1. Where standards exist, such as NAAQS for air and NPDES for water, they will govern as the action levels, where appropriate.

2. For all Class I indicator variables, short-term (within one year) trends will be examined by linear regression techniques to stated levels of significance. For air and water these will be 5%. For biology, the only Class I variables are those associated with microclimate; for these the level of significance will be 5%.

3. For annual averages obtained from all Class I variables and for selected Class II variables, long-term trends over the period of record will be examined by linear regression techniques to stated levels of significance. These are:

   a. Air & Water 5%
   b. Microclimate 5%
   c. Other biology 20%

4. In Items 2 and 3 the level of significance for which a trend could be indicated will also be stated.

5. From Items 2 and 3 above, where the trend over time is judged to be truly significant on a case-by case basis, the action level is judged to be exceeded. All variables for which the action level is exceeded will be reported to the OSO, denoted for review, discussion, and potential action on a case-by-case basis.

TABLE 3.4.4-1

Noise Class 1 Indicator Variables

Variable	Sampling Stations	
	NB01	NB15
Daytime Noise (0700 - 1900)	P	P
Nighttime Noise (1900 - 0700)	P	P

NOTE: Continuous sampling of noise is conducted for 24-hours every sixth day at both stations. The peak db level for two 12-hour intervals is designated here as P.

TABLE 3.4.5-1

Biology Class 1 Indicator Variables

	Microclimate Stations										USGS		Piceance Creek	Traffic		
Variable	BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	WU07	WU61	Road	BT01	BT02	BT03
Precipitation	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
Snow Depth	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
Temp Max	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
Temp Min	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
Periphyton																
Bioproductivity											M	M				
Deer Road Counts													W			
Deer Road Kills													W			
Traffic Count														W	W	W

NOTES: Microclimate data are collected twice monthly (2M); Periphyton, bioproductivity collected monthly (M); and Deer and Traffic are counted weekly (W).

4.0 TRACT PHOTOGRAPHY

4.1 Surface Program

4.1.1 Scope

Section 1 (C) of the Environmental Lease Stipulations requires that the Lessee conduct monitoring programs to measure perceptible changes from baseline conditions. A surface and an aerial photography program have existed since baseline to fulfill this stipulation. For the surface program, color photos were obtained annually at 35 photo points and color infrared photos were taken in the vicinity of the springs and seeps.

4.1.2 Objectives

The objectives of the surface program are to provide a visual record of changes from conditions existing prior to development operations, visual evidence of successional changes in ecosystems and, an historic account of surface development.

4.1.3 Experimental Design

Thirty-five points were selected for development monitoring from which photo pans are photographed in color. (Figure 4.1.3-1). A 35mm camera with an f 1.8, 55mm lens is used. Once each year in June between 10:00 a.m. and 2:00 p.m. under clear skies, a 360° photo pan is taken from each of the photo map stations.

A color infrared pan is taken three times during the growing season around nine spring-and-seep locations (Figure 4.1.3-2), to qualitatively record the vigor of growing vegetation at that time. These pans are contained in the semiannual data reports.

4.1.4 Archiving Methods

A complete set of the 35mm color slides for all photo points is numbered by station, aspect, and date. This set is stored in plastic envelopes, bound in three-ring binders, and filed in a unit designed to curtail dust and light as a part of the permanent record of the C.B. Shale Oil Project.

4.1.5 Results and Conclusions

The ground color slides have been archived as a photographic record of Tract changes, as in the previous years. Color infrared photo pans of the areas around the springs and seeps were taken three times during the growing season to record qualitative changes during the vegetative growth cycle.

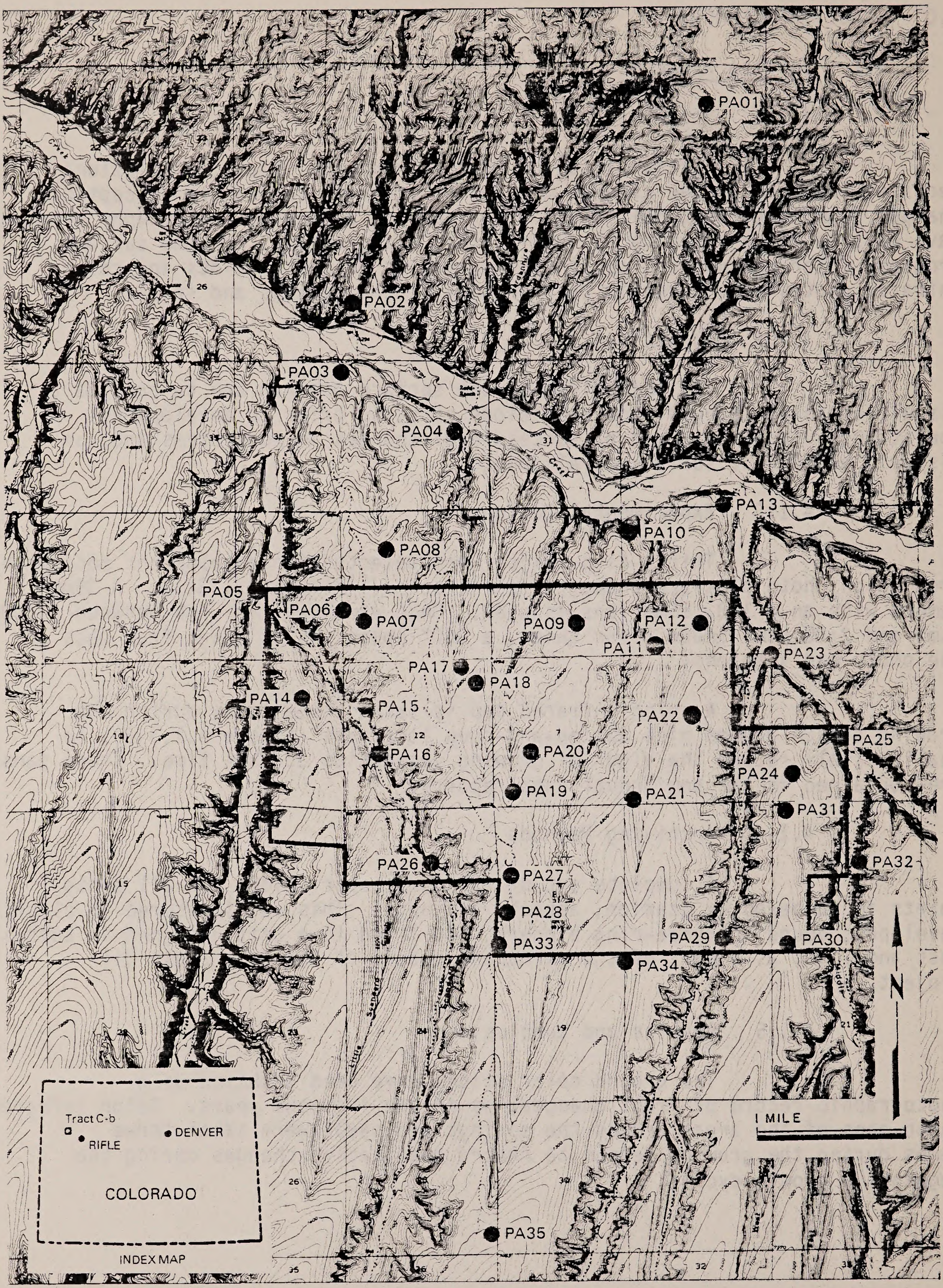


FIGURE 4.1.3-1
SURFACE COLOR PHOTOGRAPHY NETWORK

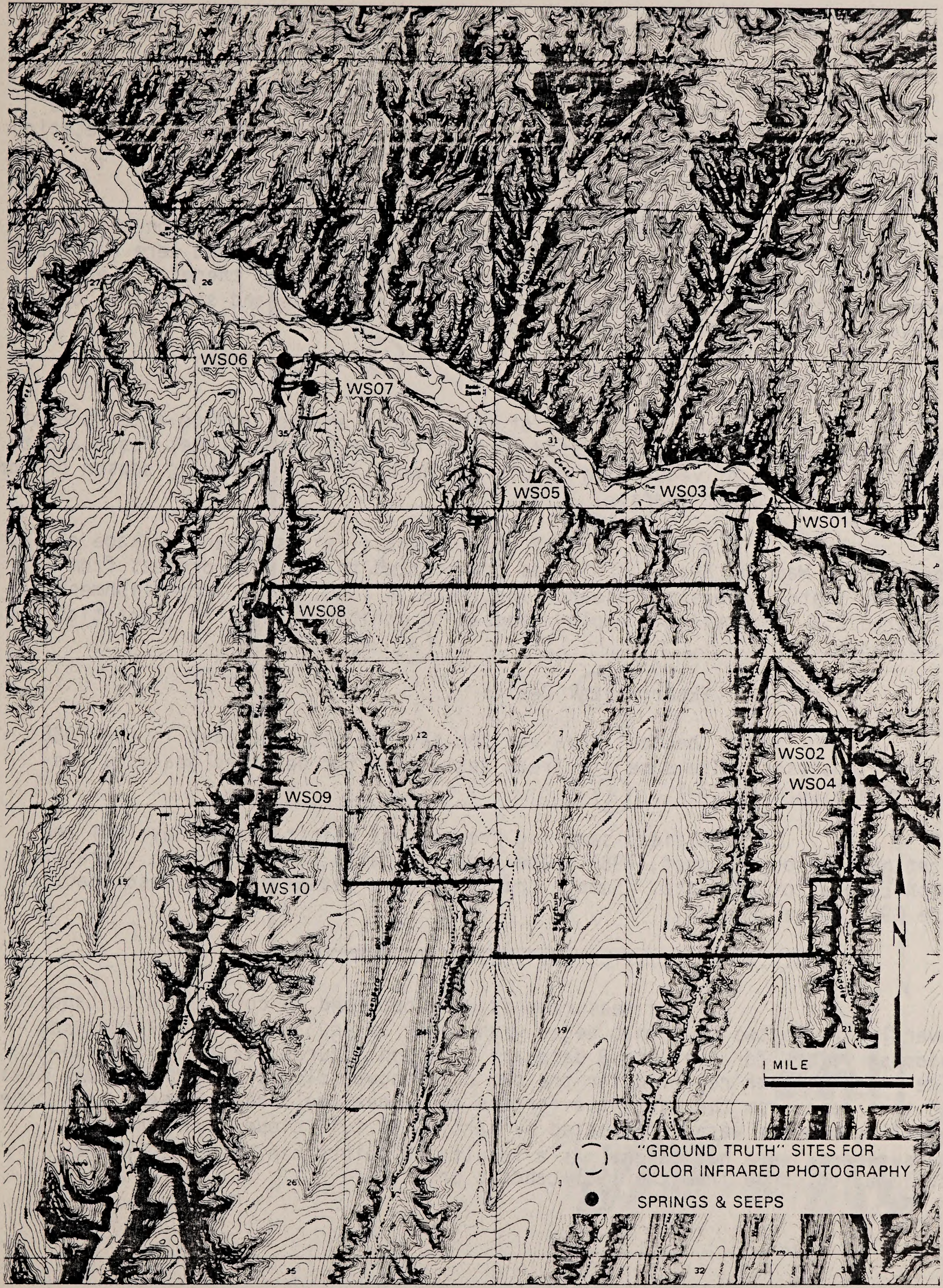


FIGURE 4.1.3-2
COLOR IR PHOTOGRAPHY STATIONS

4.2 Remote Sensing

4.2.1 Scope

Digital data from the multi-spectral scanner aboard the Landsat series of earth-orbiting satellites were used to assess the vegetation condition in the vicinity of the C-b Tract. The wide area coverage and resolution are adequate for general vegetation condition assessment.

The measure of vegetation condition is based on results obtained by Maxwell, et. al. (1980). The methods they employed were developed for short grass prairie and irrigated row crop vegetation; therefore, an extension of these methods to the pinyon-juniper forests and shrublands of the Piceance Basin has been derived.

4.2.2 Objectives

The objectives of this effort are to provide a measure of vegetation condition for a selected portion of the Piceance Creek Basin and to provide a measure of vegetation condition change during a growing season or for comparison with other years.

A major part of the image analysis software package called the Landsat Mapping System (LMS) was transferred to the C.B. project from Colorado State University Research Institute in 1980. This accomplishment has prepared C.B. to routinely employ Landsat to monitor changes in vegetation condition.

4.2.3 Experimental Design

The test area was the same as the area used in the 1980 Landsat analysis. The same six areas designated for detailed analysis are shown on Figure 4.2.3-1.

A field sampling program was initiated in May 1981 and continued through August, 1981. The sampling dates were chosen to correspond with Landsat overflights. Sample transects were established as described in the 1980 Annual Report.

4.2.4 Discussion and Results

Field measurements were obtained to coincide with Landsat overflights on two days that began with clear skies. Estimated vs measured biomass values for the June 9 date are shown on Figures 4.2.4-1 and 4.2.4-2. The imagery later received for the two days showed clouds over the sample areas so that data from the satellite for the test area could not be used. All other overflight dates were accompanied by partial or full cloud cover and field measurements were not taken. As a result, no points can be added to the calibration curve from the 1981 Landsat program.

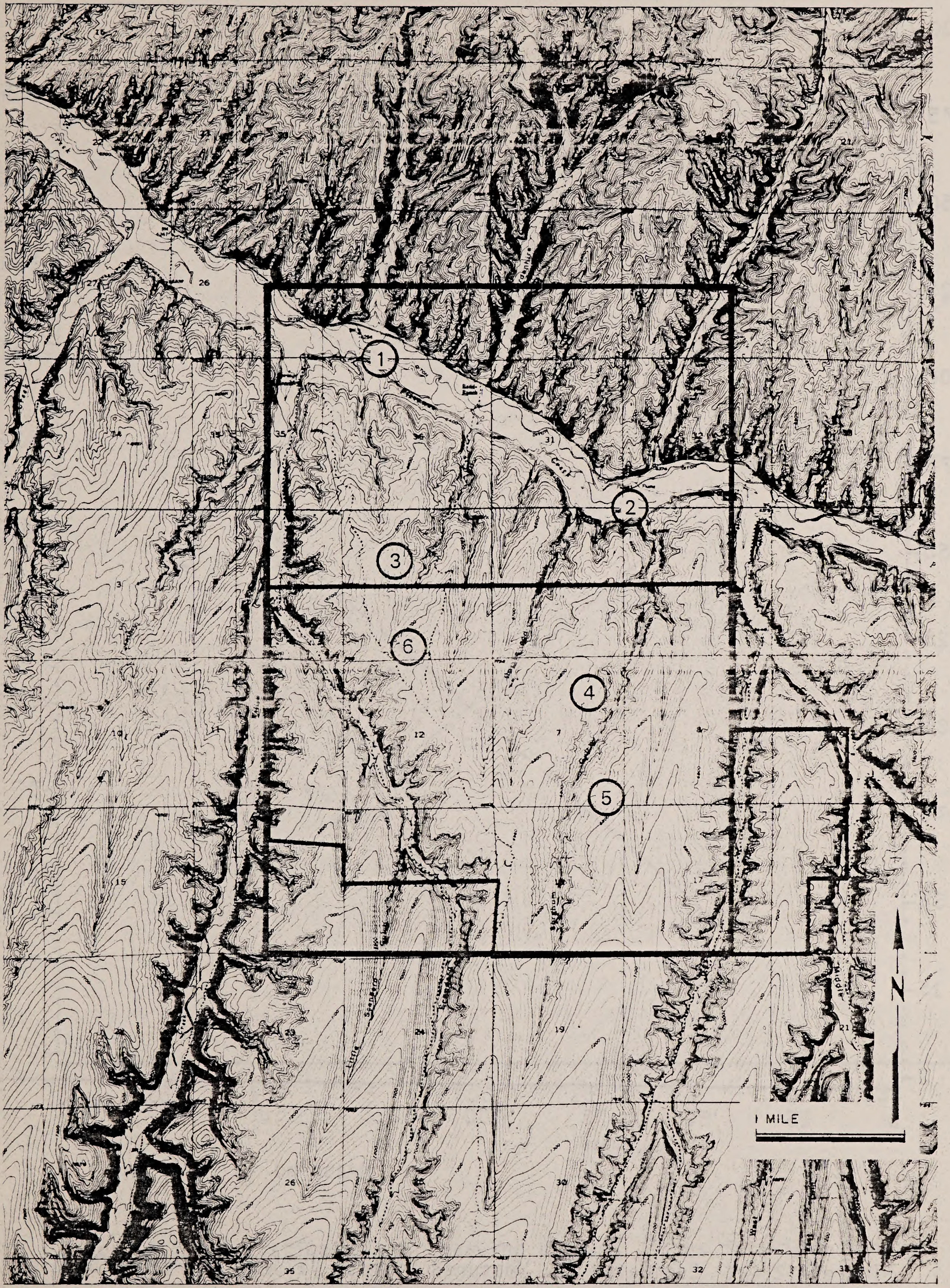


FIGURE 4.2.3-1
LANDSAT TEST AREA AND SIX AREAS OF CONCERN

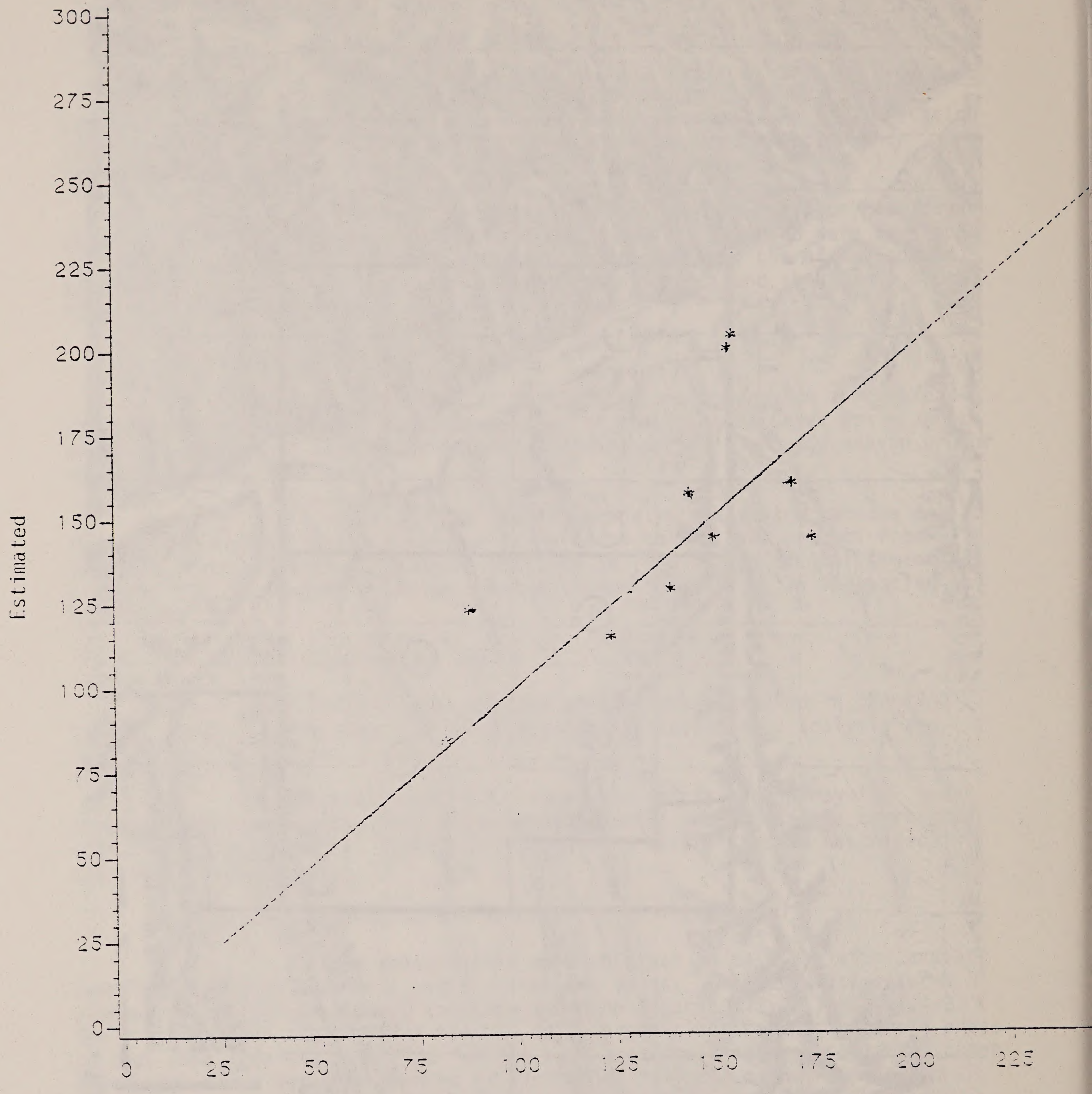


Figure 4.2.4-1 Estimated vs. Measured Biomass Values for Meadow Samples

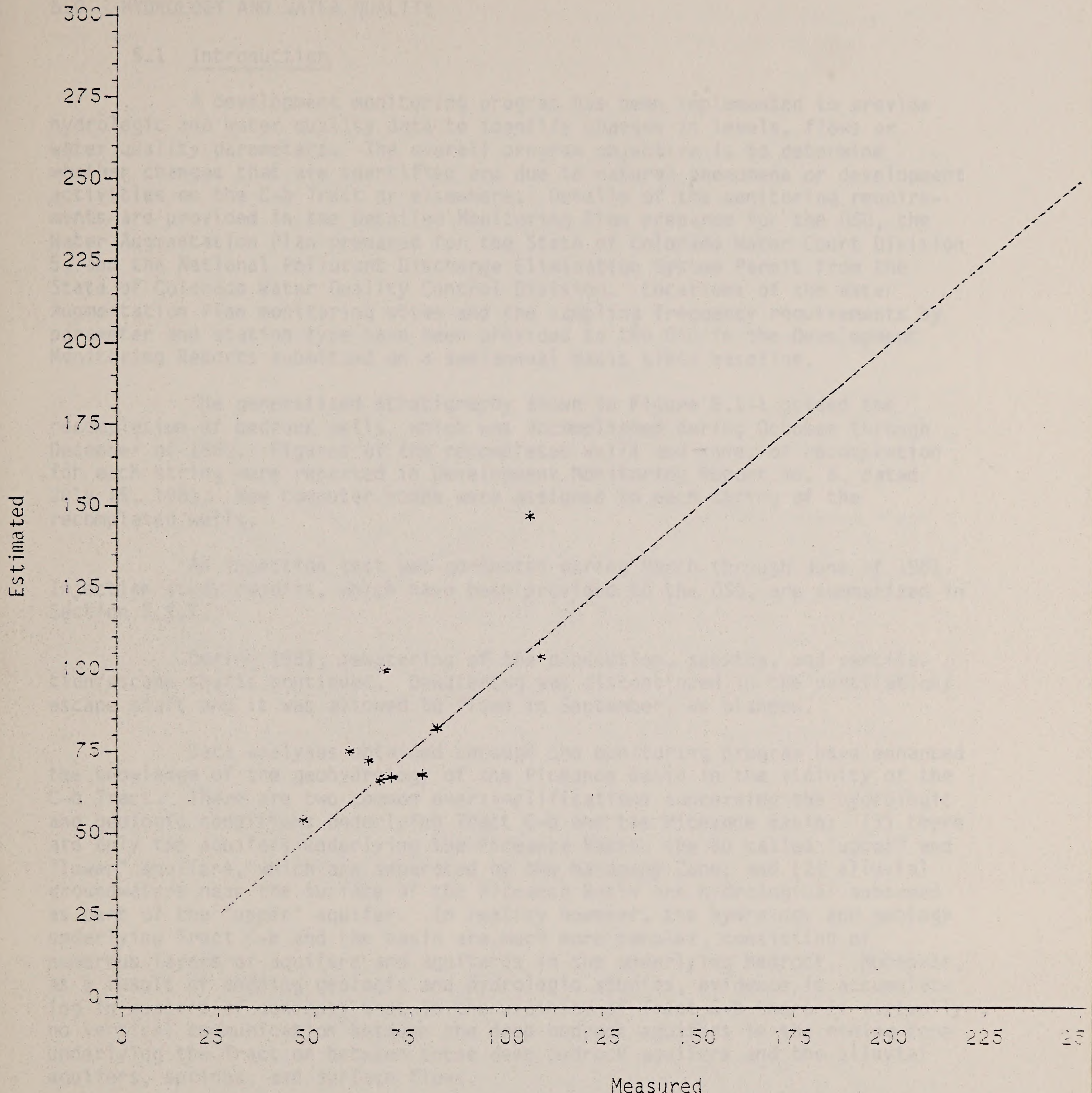


Figure 4.2.4-2 Estimated vs. Measured Biomass Values for Ridge Samples

5.0 HYDROLOGY AND WATER QUALITY

5.1 Introduction

A development monitoring program has been implemented to provide hydrologic and water quality data to identify changes in levels, flows or water quality parameters. The overall program objective is to determine whether changes that are identified are due to natural phenomena or development activities on the C-b Tract or elsewhere. Details of the monitoring requirements are provided in the Detailed Monitoring Plan prepared for the OSO, the Water Augmentation Plan prepared for the State of Colorado Water Court Division 5, and the National Pollutant Discharge Elimination System Permit from the State of Colorado Water Quality Control Division. Locations of the Water Augmentation Plan monitoring sites and the sampling frequency requirements by parameter and station type have been provided to the OSO in the Development Monitoring Reports submitted on a semiannual basis since baseline.

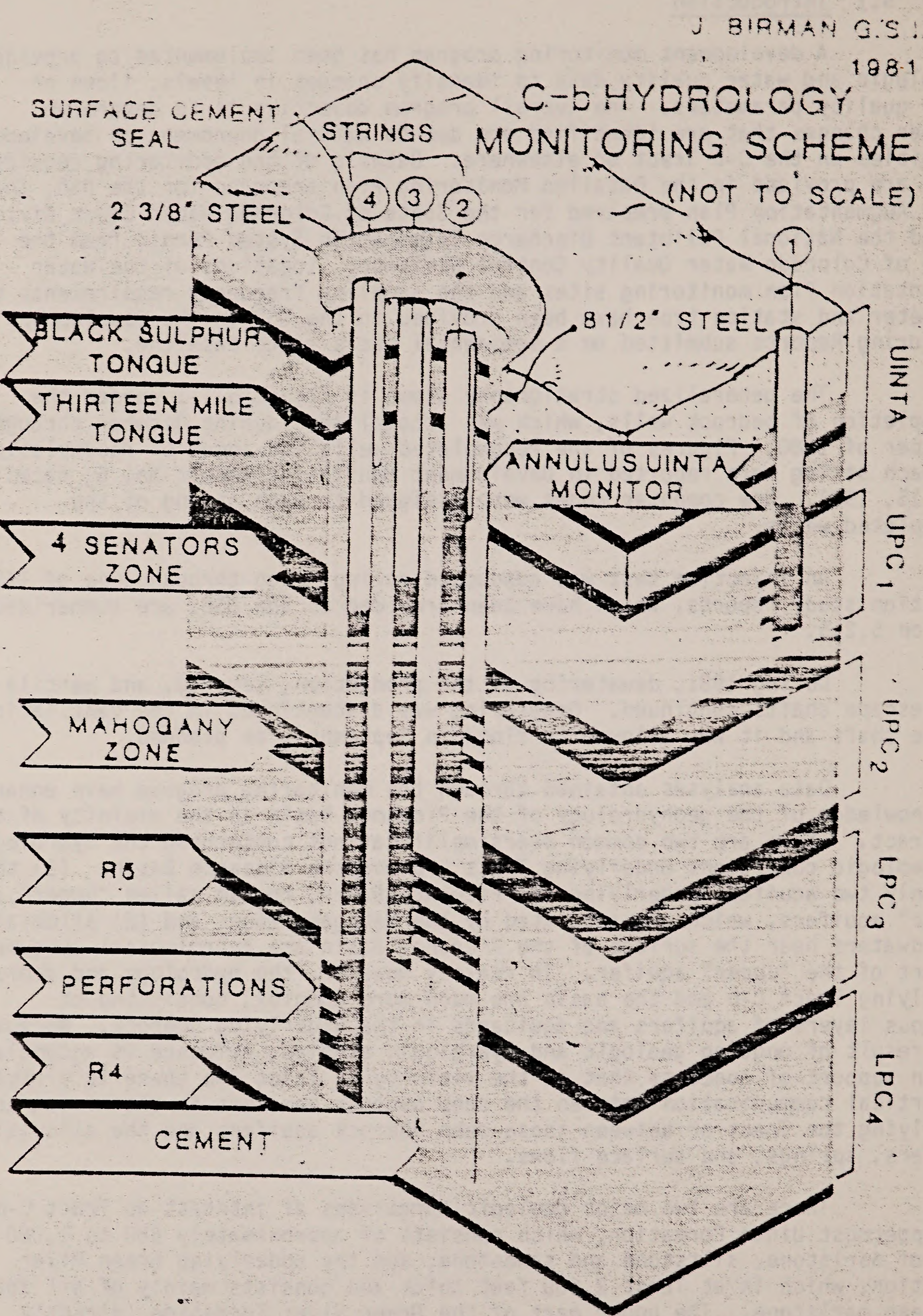
The generalized stratigraphy shown in Figure 5.1-1 guided the recompletion of bedrock wells, which was accomplished during October through December of 1980. Figures of the recompleted wells and zones of recompletion for each string were reported in Development Monitoring Report No. 6, dated July 15, 1981. New computer codes were assigned to each string of the recompleted wells.

An injection test was conducted during March through June of 1981. Injection study reports, which have been provided to the OSO, are summarized in Section 5.2.5.

During 1981, dewatering of the production, service, and ventilation/escape shafts continued. Dewatering was discontinued in the ventilation/escape shaft and it was allowed to flood in September, as planned.

Data analyses obtained through the monitoring program have enhanced the knowledge of the geohydrology of the Piceance Basin in the vicinity of the C-b Tract. There are two common oversimplifications concerning the hydrologic and geologic conditions underlying Tract C-b and the Piceance Basin: (1) there are only two aquifers underlying the Piceance Basin, the so called "upper" and "lower" aquifers, which are separated by the Mahogany Zone; and (2) alluvial groundwaters near the surface of the Piceance Basin are hydrological subsumed as part of the "upper" aquifer. In reality however, the hydrology and geology underlying Tract C-b and the basin are much more complex, consisting of numerous layers of aquifers and aquitards in the underlying bedrock. Moreover, as a result of ongoing geologic and hydrologic studies, evidence is accumulating in support of concepts that in the vicinity of Tract C-b there is virtually no vertical communication between the deep bedrock aquifers in the mining zone underlying the Tract or between those deep bedrock aquifers and the alluvial aquifers, springs, and surface flows.

There are two major geologic formations of interest at Tract C-b: the uppermost Uinta Formation, which consists of approximately 500 to 1,000 feet of marlstone, siltstone and sandstone; and the underlying Green River Formation, which is at least 2,000 feet thick and consists mainly of oil shale and lean marlstone. The upper part of the Green River Formation (directly under the Uinta Formation) is the Parachute Creek Member. The Uinta Formation



J. BIRMAN G.S.I.
1981
C-b HYDROLOGY
MONITORING SCHEME
(NOT TO SCALE)
SURFACE CEMENT
SEAL
STRINGS
2 3/8" STEEL
4
3
2
1
8 1/2" STEEL
BLACK SULPHUR
TONGUE
THIRTEEN MILE
TONGUE
ANNULUS UINTA
MONITOR
4 SENATORS
ZONE
MAHOGANY
ZONE
R5
PERFORATIONS
R4
CEMENT
UINTA
UPC 1
UPC 2
LPC 3
LPC 4

Figure 5.1-1

and the Parachute Creek Member contain several zones of very low permeability that act as aquicludes and aquitards. These zones help to confine the groundwater into distinct and numerous hydrologic units.

In the Parachute Creek Member there are several tight, rich oil shale units which are (in increasing order of depth) the Four Senators Zone, the Mahogany Zone, and the R-6, R-5, and R-4 Zones. These tight zones confine the deep bedrock groundwaters of the Parachute Creek Member into at least four major hydrologic units (in increasing depth): UPC1, approximately between Thirteen Mile Creek Tongue and the Four Senators Zone; UPC2, approximately between the Four Senators Zone and the Mahogany Zone; LPC3, approximately between the Mahogany Zone and the R-5 Zone; and LPC4, approximately between the R-5 Zone and the R-4 Zone.

In the Uinta formation, two interbedded marlstone tongues of the upper Green River formation are important aquitards or aquicludes. These are the Black Sulphur tongue in the middle of the Uinta formation, and the Thirteen Mile Creek tongue near the base of the formation. These are tight zones, which we believe cause confining conditions in the Uinta formation between the Black Sulphur tongue and the Thirteen Mile Creek tongue. The Black Sulphur tongue appears to be the base of an unconfined or "water table" aquifer in the upper Uinta formation.

Set within the Uinta formation (or within the Green River formation where it is exposed east of the Tract), there are alluvial aquifers in the valleys of the major streams (such as Piceance Creek) and their tributaries. The alluvium ranges in depth from a few tens of feet to a little more than 100 feet, and consists of unconsolidated sand, gravel, silt and clay. Some of these alluvial aquifers may also be hydrologically connected to the unconfined "water table" aquifer above the Black Sulphur Tongue.

Until recently the UPC1 designation generally included <u>all</u> the groundwater above the Four Senators Zone, unconfined and confined aquifer groundwater in the Uinta Formation, and bedrock groundwaters in the Parachute Creek Member. Based on new data discussed below, C.B. now believes that the confined aquifer in the lower Uinta Formation should be recognized as separate and distinct from the UPC1 aquifer in the Parachute Creek Member, from the unconfined aquifer of the upper Uinta and alluvial aquifers.

Data collected over the past two years strongly suggest that the tight, confining zones of oil shale highly restrict the vertical movement of groundwater between the major hydrologic units. Some of the data in this regard come from two well pairs along Piceance Creek north of the Tract. Each well pair consists of a deep bedrock well and an alluvial well within close proximity of one another, and designed to determine whether the dewatering activities in the deep bedrock aquifers are affecting the alluvial aquifers. As shown in Figures 5.1-2 and 5.1-3, the depressurizing effects that have been detected and measured in the deep bedrock wells have not been observed to date in the alluvial companions, providing evidence that they are not hydrologically connected. Supporting data and results are discussed in detail in Section 5.2.5.

These data are consistent with other data from drill stem tests measuring the permeability of the formation, including the oil shale. Those

Figure 5.1-2

COMPARISON OF WATER LEVELS IN CB WELL PAIRS DURING SHAFT DEVELOPMENT

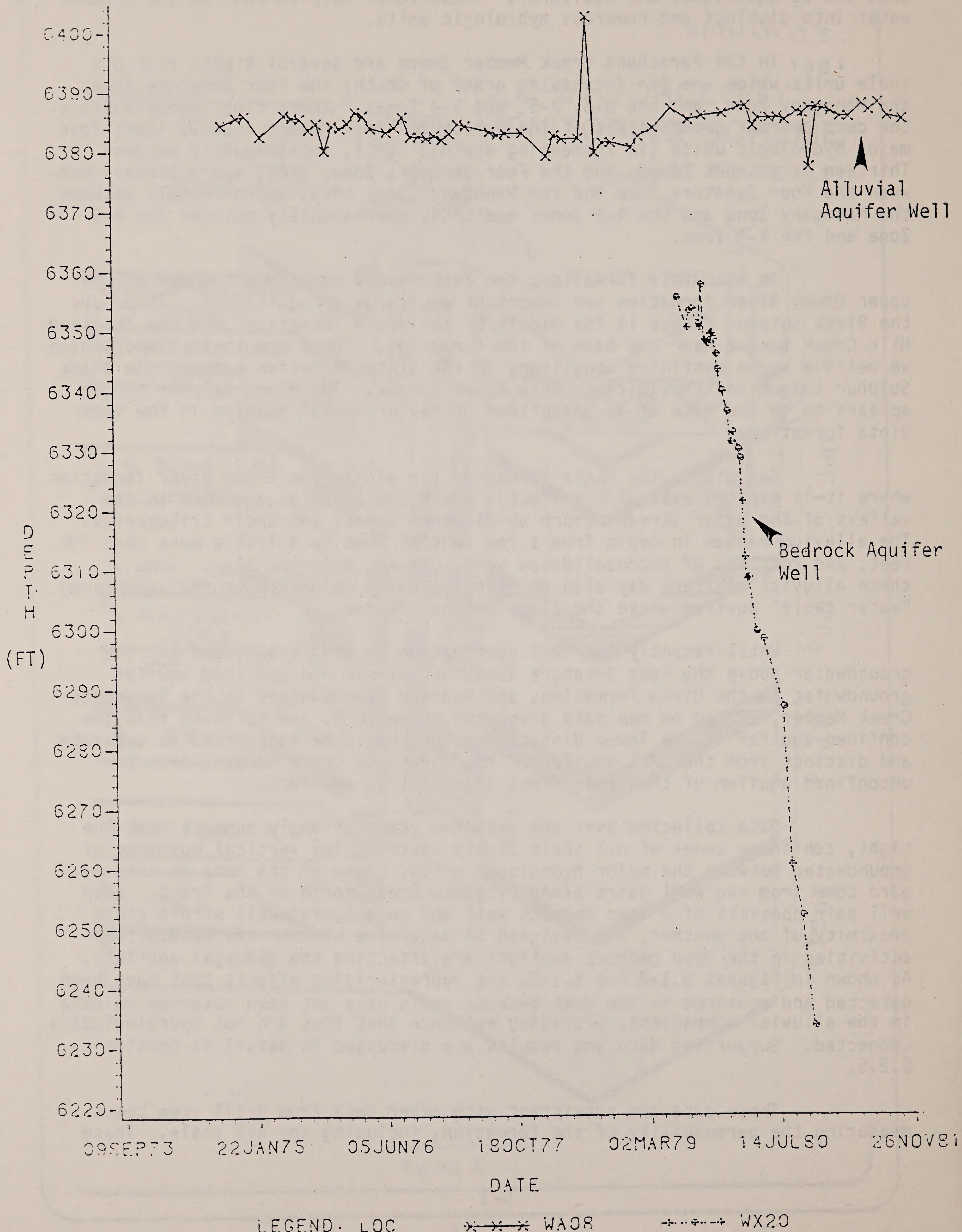
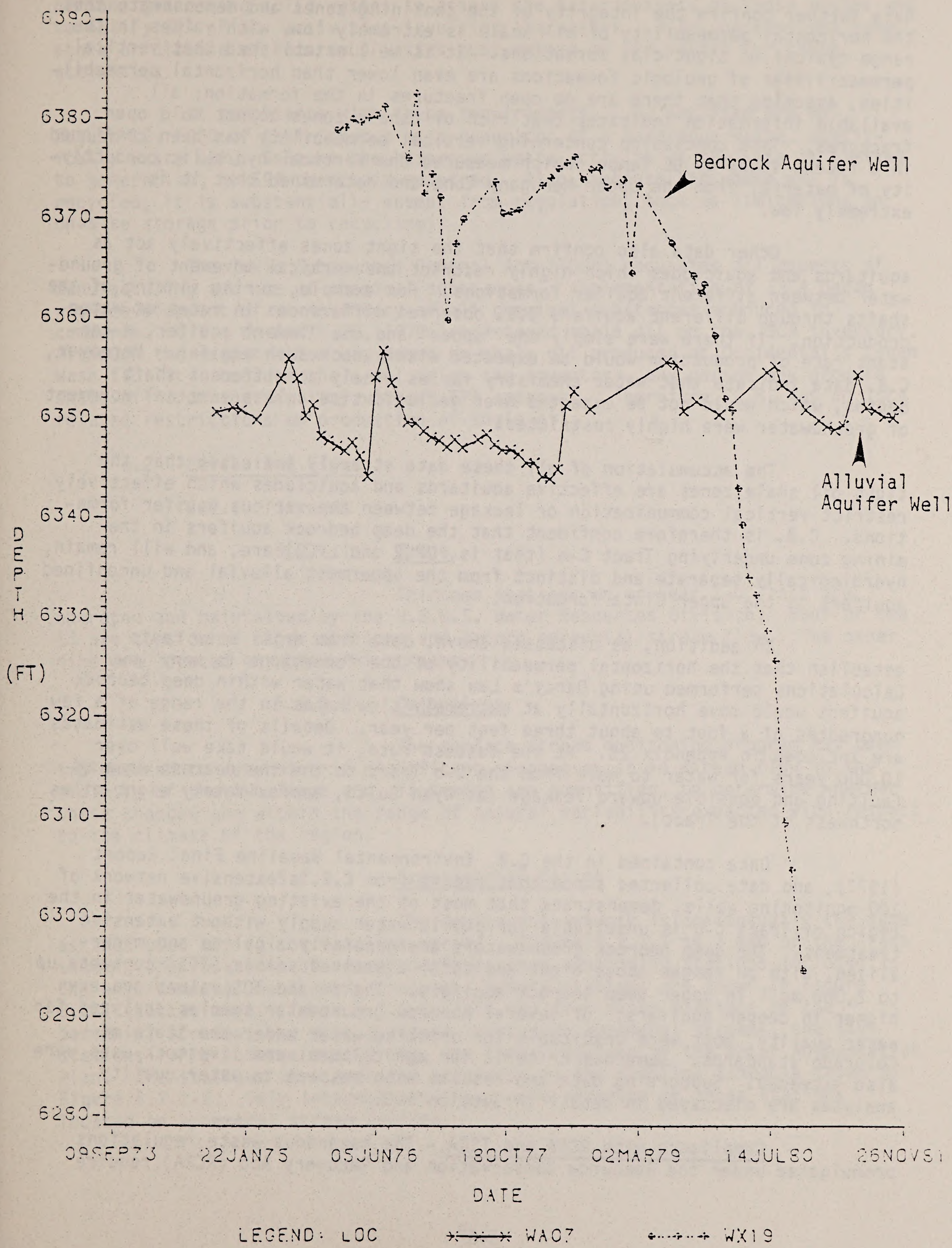


Figure 5.1-3

COMPARISON OF WATER LEVELS IN CB WELL PAIRS DURING SHAFT DEVELOPMENT



data further confirm the integrity of the confining zones and demonstrate that the horizontal permeability of oil shale is extremely low, with values in the range typical of tight clay formations. It is well established that vertical permeabilities of geologic formations are even lower than horizontal permeabilities, assuming that there are no open fractures in the formation; all available information indicates that rich oil shale zones do not hold open fractures. This conclusion concerning vertical permeability has been confirmed in a recent study by GE Tempo, which measured the vertical hydraulic conductivity of material from the upper Mahogany Zone and determined that it is extremely low.

Other data also confirm that the tight zones effectively act as aquitards and aquicludes which highly restrict the vertical movement of groundwater between different aquifer formations. For example, during sinking of the shafts through different aquifers C.B. observed differences in rates of water production. If there were simply one "upper" and one "lower" aquifer, a constant rate of production would be expected within each such aquifer. Moreover, C.B. data indicate that water chemistry varies widely at different shaft depths, which would not be expected over geologic time unless vertical movement of groundwater were highly restricted.

The accumulation of all these data strongly indicates that the tight oil shale zones are effective aquitards and aquicludes which effectively restrict vertical communication or leakage between the various aquifer formations. C.B. is therefore confident that the deep bedrock aquifers in the mining zone underlying Tract C-b (that is, UPC2 and LPC3) are, and will remain, hydrologically separate and distinct from the uppermost alluvial and unconfined aquifers in the upper Uinta formation.

In addition, as discussed above, data from drill stem tests establish that the horizontal permeability of the formations is very low. Calculations performed using Darcy's Law show that water within deep bedrock aquifers would move horizontally at extremely slow rates in the range of a few hundredths of a foot to about three feet per year. Details of these estimates are included in Appendix 2B. At the fastest rate, it would take well over 10,000 years for water to move from the C-b Tract to the the nearest area of faulting and possible upward leakage (at Ryan Gulch, approximately eight miles northwest of the Tract).

Data contained in the C.B. Environmental Baseline Final Report (1977), and data collected since that report from C.B.'s extensive network of 100 monitoring wells, demonstrate that most of the existing groundwater in the region of Tract C-b is unsuitable for public water supply without extensive treatment. The deep bedrock groundwaters are generally alkaline and mineralized, with pH ranges above eight and total dissolved solids (TDS) contents up to 2,000 mg/l in upper deep bedrock aquifers. The pH and TDS values are even higher in deeper aquifers. Of several hundred groundwater samples analyzed for water quality, most were unsuitable for drinking water under the State of Colorado standards. Numerous criteria for agricultural and livestock uses were also exceeded. Supporting data and results with respect to water quality analyses are discussed in detail in Section 5.3.

<u>Compliance with RCRA and TSCA</u> - The hazardous waste regulations promulgated under the Resource Conservation and Recovery Act (RCRA) require

persons generating solid wastes to assess the hazardousness of those wastes and to notify EPA of any activities involving the wastes. Also, persons who treat, store or dispose of hazardous wastes must obtain an EPA permit for those activities.

In compliance with these requirements, C.B. notified EPA on August 15, 1980 of their status as a generator of a hazardous waste, specifically waste oil. Because the hazardous waste activity at the site is limited to generation, no EPA permit is required. Also, because the waste oil is recycled, it is substantially exempt from regulation, such as limitations on on-site storage prior to recycling.

The Toxic Substances Control Act (TSCA) regulates all aspects of manufacturing and use of chemical substances. Implementation of TSCA began with development of an inventory of all chemical substances produced in commerce. C.B., on April 26, 1978, registered shale oil on the TSCA inventory. Although the registration was based on shale oil produced at Occidental's Logan Wash facility, because shale oil is on the inventory, any person may produce shale oil from any facility without EPA approval. Therefore, C.B. has no TSCA related restrictions on production of shale oil.

5.2 Levels and Flows

5.2.1 Streams

5.2.1.1 Scope

Thirteen stations on or near C-b Tract are operated and maintained by the U.S.G.S. Water Resources Division. Four of the 13 are considered major stations and record perennial stream flow. The other nine are located on ephemeral streams.

5.2.1.2 Objectives

The surface stream monitoring program has been implemented to determine if significant changes exist in stream flow in the vicinity of the C-b Tract and, if trends are identified, to determine whether these changes are within the range of natural variability expected with respect to the climate of the region.

5.2.1.3 Experimental Design

The monitoring network is conceptually the same as that used during the baseline period. Figure 5.2.1-1 is a map of the Tract showing the locations of nearby surface water monitoring stations included in the environmental monitoring program. Remote stations are shown in Figure 2.2-1 (jacket map). Table 5.2.1-1 lists the four major stations on the perennial streams, the nine stations located on ephemeral streams, the six stations for discharge monitoring, and those required by the Water Augmentation Plan. The stations were operated according to the sampling schedule shown on Figure 5.2.1-2. Only intermittent flows were recorded at those stations located on ephemeral stream courses.

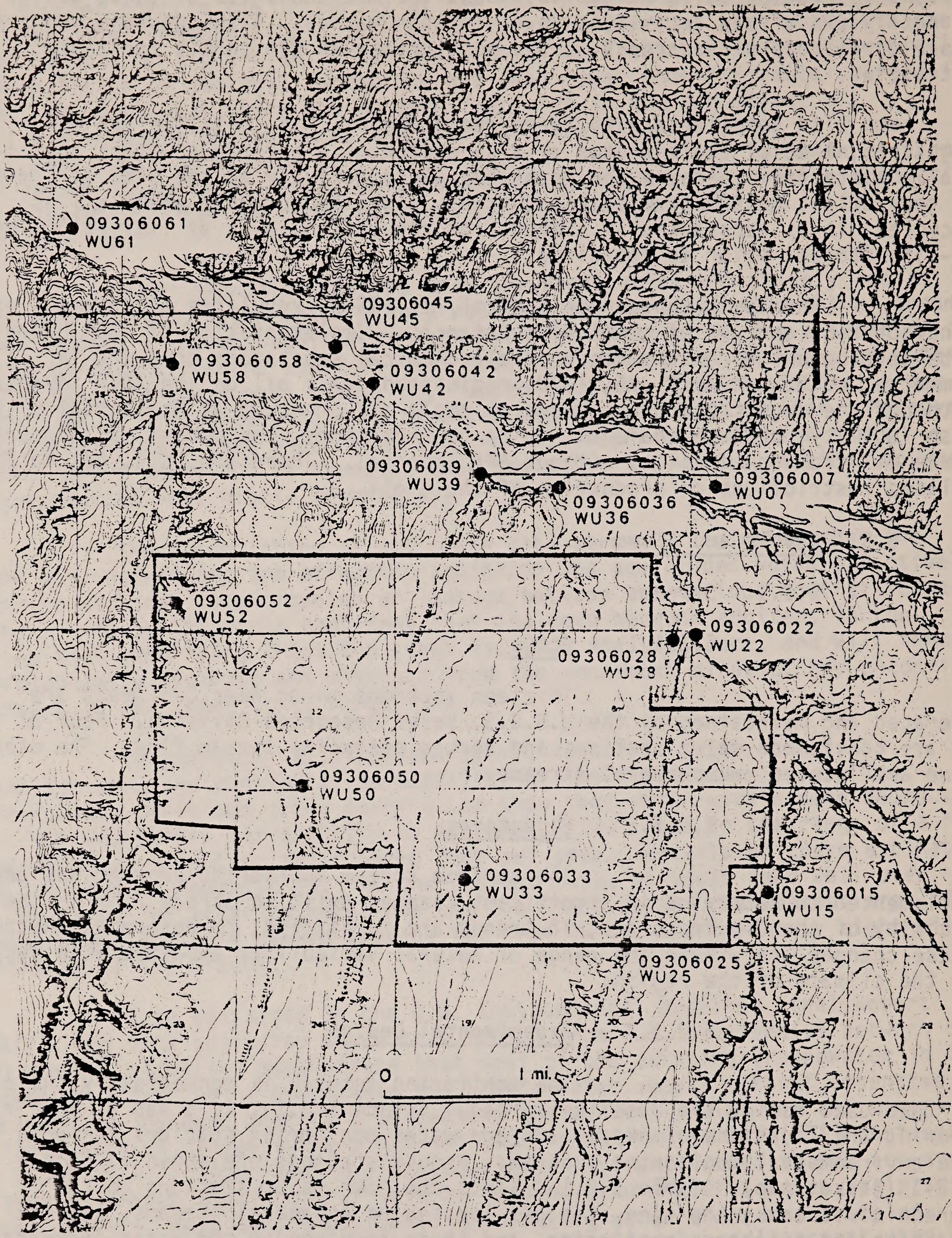


Figure 5.2.1-1
U.S.G.S Stream Gauging Station Monitoring Network

TABLE 5.2.1-1
STATIONS CONSTITUTING THE SURFACE WATER MONITORING PROGRAM

Computer Code	USGS Number	Station Location	Comments
W007	09306007	Piceance Creek below Rio Blanco, upstream from C-b Tract	To operate during the life of the Project. Baseline flow since April 1974, a major station. Continuous flow measurements.
W061	09306061	Piceance Creek at Hunter Creek, downstream from C-b Tract	To operate during the life of the Project. Baseline flow since April 1974, a major station. Continuous flow measurements.
W022	09306022	Stewart Gulch	Consider reduction if data are stable after a period of commercial operations. A major station. Baseline flow data since October 1974.
W058	09306058	Willow Creek	Consider reduction if data are stable after a period of commercial operations. A major station. Baseline flow data since October 1974.
W000	09306200	Piceance Creek near Ryan Gulch	One of the major monitoring stations on Piceance Creek. Baseline flow data since October 1964.
W042	09306042	In "No Name Gulch" west of Cottonwood Gulch on C-b Tract	Used to monitor construction activities and mine area development. Ephemeral station. Baseline flow data since April 1974.
W036	09306036	At mouth of Sorghum Gulch	To operate during the life of the Project. To monitor runoff from construction activities. Baseline flow since April 1974. Ephemeral station.
W033	09306033	In Sorghum Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral station.
W039	09306039	At mouth of Cottonwood Gulch	To operate during the life of the Project. To monitor stream runoff from surface facilities, ore storage piles, roads and construction areas. Ephemeral station. Baseline data since April 1974.
W052	09306052	At mouth of Scandard Gulch	To operate during the life of the Project. Baseline data since October 1974. Ephemeral station.
W050	09306050	In Scandard Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral station near southern boundary of C-b.
W028	09306028	At mouth of West Fork of Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since April 1974.
W025	09306025	In West Fork Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since April 1974. Ephemeral station.
W015	09306015	In Middle Fork Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral Station.
W033	09306033	In Sorghum Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. To monitor runoff from construction activities. Baseline data since October 1974. Ephemeral station.
W045	09306045	Piceance Creek 50 meters downstream from No Name Gulch and Piceance Creek confluence	New station constructed to monitor discharges from C-b Tract through No Name Gulch.
W048	09304800	White River below Meeker	New station required by Water Augmentation Plan.
W055	09306255	Yellow Creek near White River	New station required by Water Augmentation Plan.
W062	09306222	Piceance Creek at White River	New station required by Water Augmentation Plan.

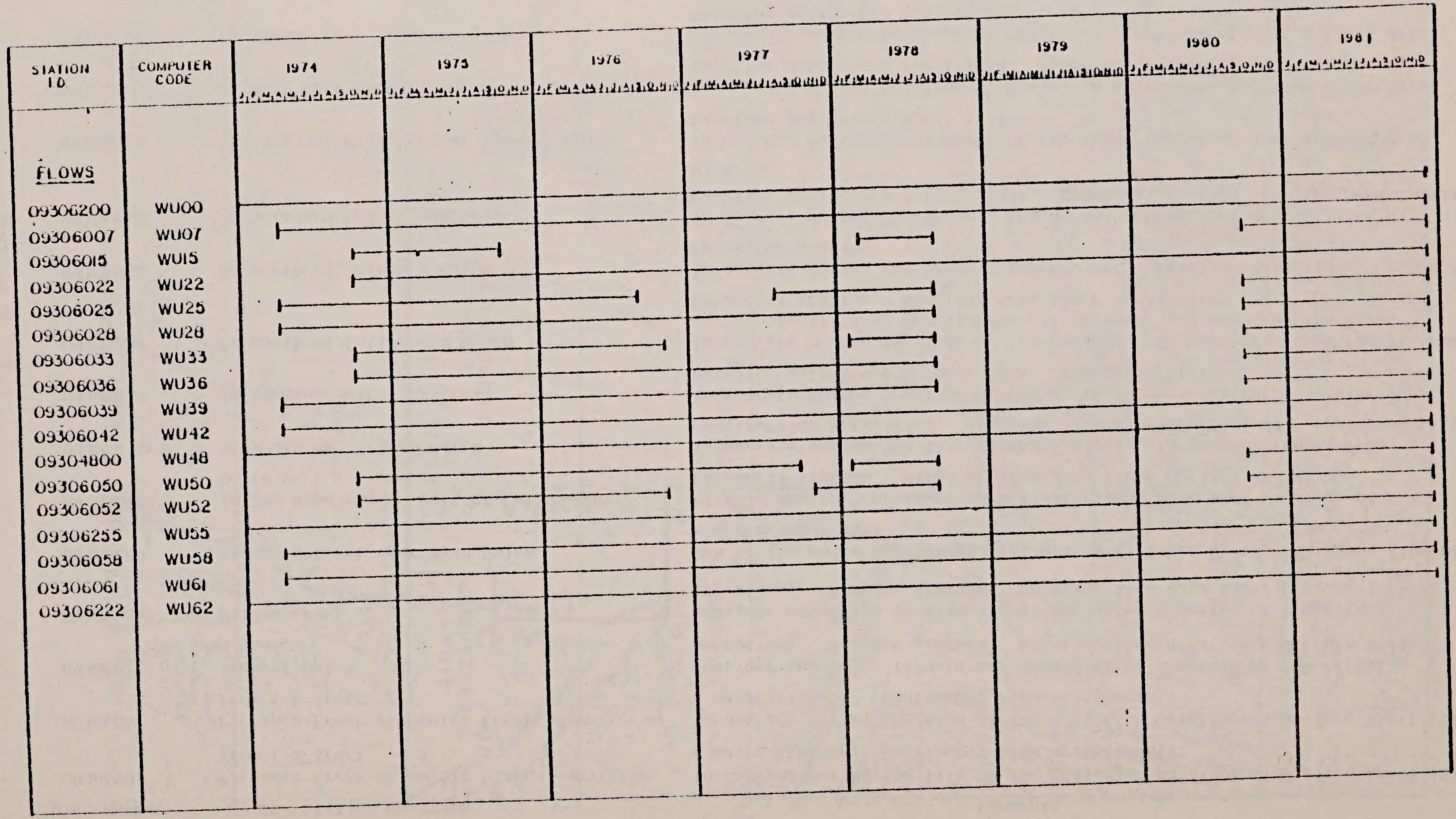


FIGURE 5.2.1-2
U.S.G.S. STREAM GAUGING STATIONS
SAMPLING TIME INTERVALS
FOR FLOWS

5.2.1.4 Methods of Analysis

Analyses were performed by comparison of total and mean annual streamflow data, by analysis of ratios of flows from different stations, by analyzing the long term trends over time since baseline using the Box-Jenkins statistical technique (Box and Jenkins, 1976), and by analyzing short-term trends over time during the most recent water year using linear regression analysis.

5.2.1.5 Discussion and Results

Hydrographs of mean daily flow for three major stations are shown as Figure 5.2.1-3. These hydrographs show the seasonal influences of runoff, evapotranspiration, and irrigation diversions. Table 5.2.1-2 shows the total annual and mean daily stream flows for station WU07, WU61, WU00, WU22 and WU58. Even though the hydrographs are affected by irrigation diversions, the total flow in 1981 was 73 percent of the average flows measured at WU61 during the period from 1975 through 1980. At WU07, the total annual flow was 55 percent of the average for the years 1975 through 1980. Flows measured at WU22 and WU58 were 5 and 13 percent greater than the 1975 to 1980 average flow. The large flows in 1979 and 1980 were immediately followed by a year of lower flow, which indicates the climatic variability of the region.

Trend analysis through the use of the Box-Jenkins statistical technique for flows at stations WU07 and WU61 concluded that no time trends are apparent in the data since baseline.

5.2.2 Springs and Seeps

5.2.2.1 Scope

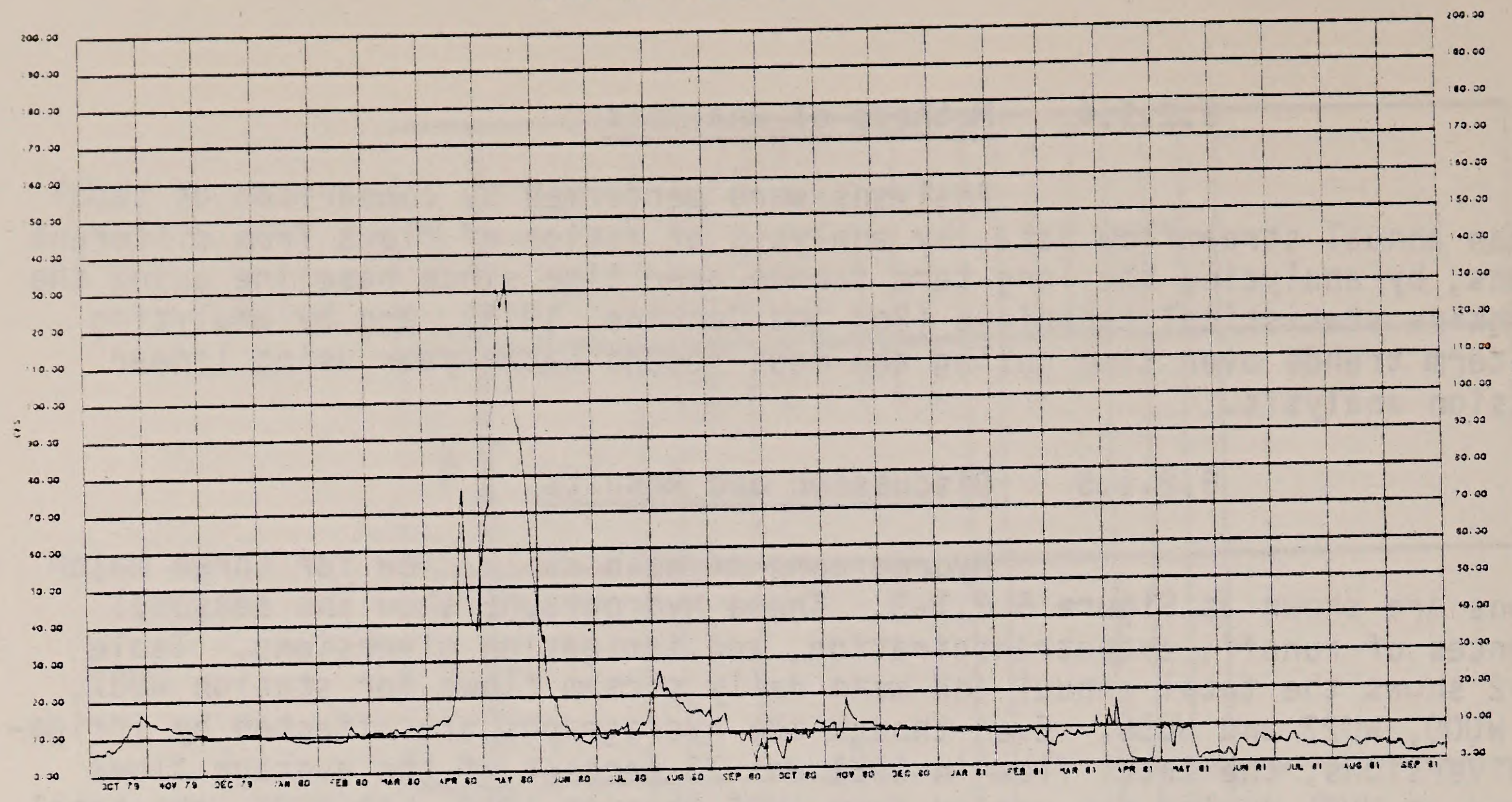
The flow from natural springs and seeps provides a substantial fraction of the volumetric low level stream flows to Piceance Creek. The source areas for the springs and seeps have not been documented. Although none of the springs that were monitored are located within the C-b Tract boundaries, flow data were obtained from nine springs located on the western and eastern Tract boundaries and along Piceance Creek. The Water Augmentation Plan added monitoring requirements for springs identified as S-10A, S-1-1, and S-102. Figures 5.2.2-1 and 5.2.2-2 shows the springs and seeps locations. Figure 5.2.2-3 shows the springs and seeps identification numbers and the sampling schedule for the measurement of flows. Meteorological stations on and adjacent to the Tract provided precipitation data for comparison with spring flows.

5.2.2.2 Experimental Design

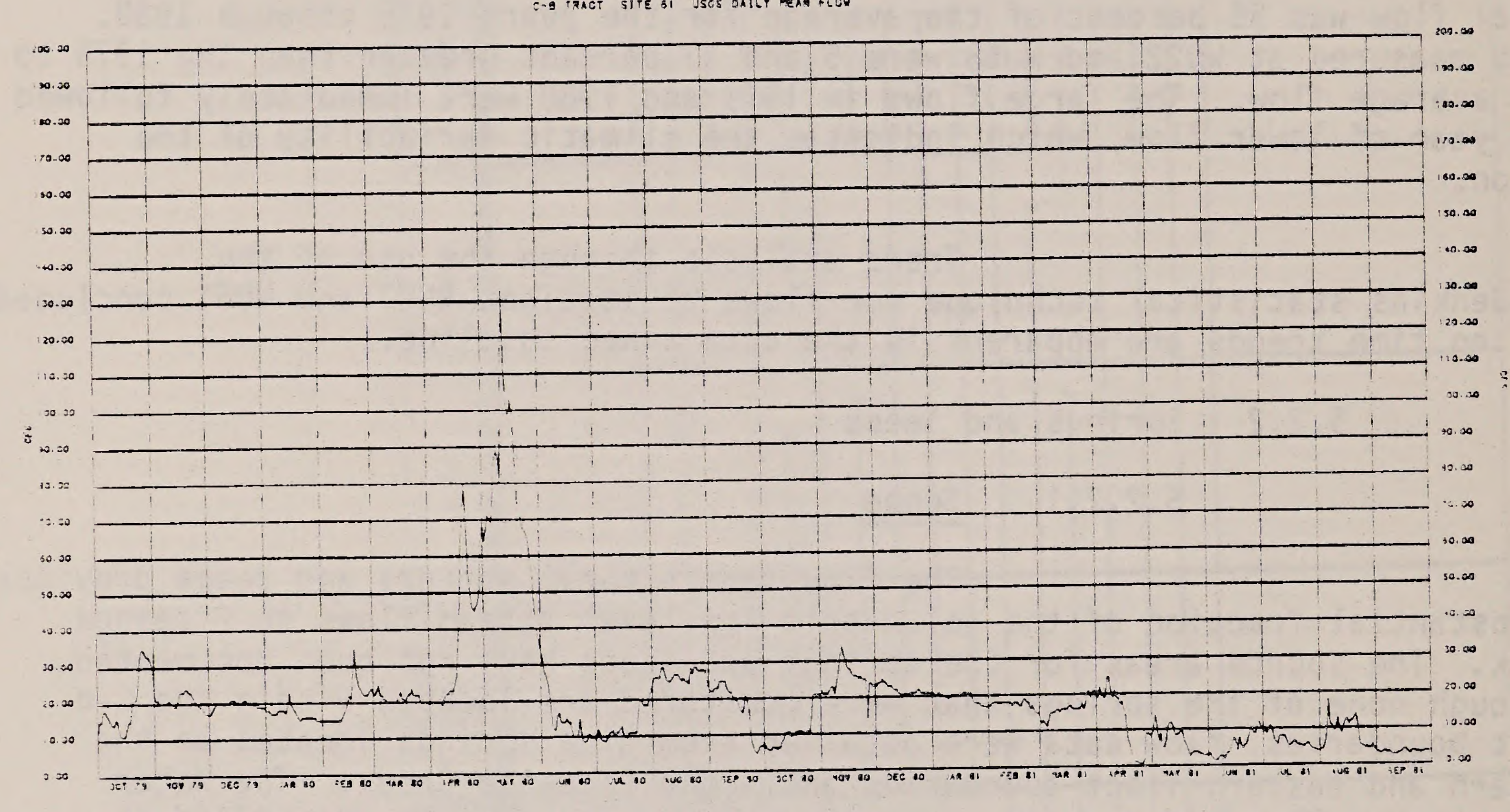
The design concept is to measure the flow of springs and seeps on a weekly schedule throughout the year, and to use the data produced to attempt to determine the location of source areas for springs. If the source were proximal, precipitation on or near the Tract should be reflected quite rapidly in the spring outflow. In addition, periods of little or no precipitation or drought conditions should cause reduction in spring flows.

FIGURE 5.2.1-3

C-B TRACT SITE 7 USGS DAILY MEAN FLOW



C-B TRACT SITE 61 USGS DAILY MEAN FLOW



C-B TRACT SITE 200 USGS DAILY MEAN FLOW

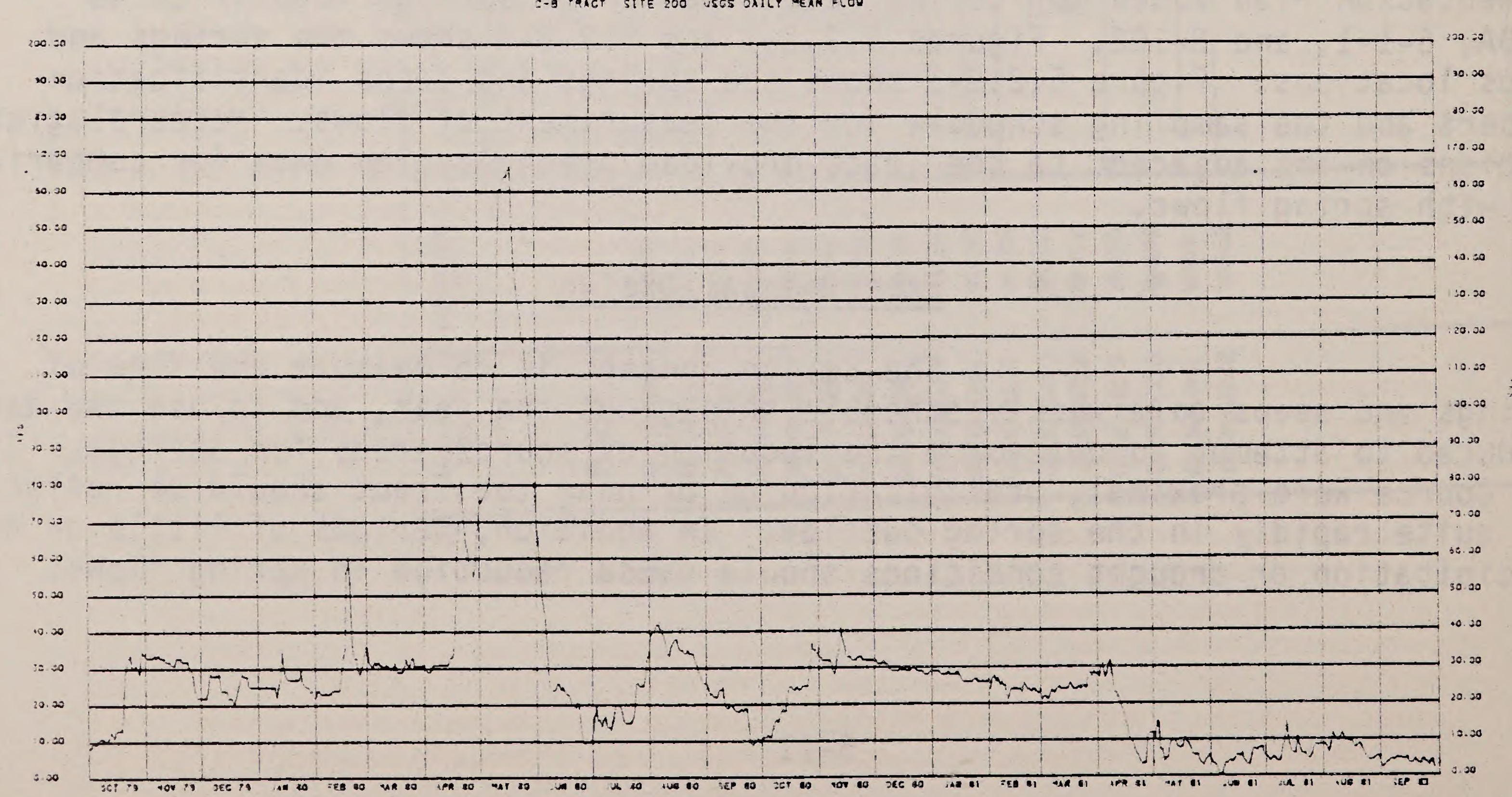


TABLE 5.2.1-2 TOTAL ANNUAL AND MEAN DAILY STREAMFLOW

Water Year	Station									
	WU07		WU22		WU58		WU61		WU09	
	Total Flow Cu Ft	Mean Flow CFS	Total Flow Cu Ft	Mean Flow CFS	Total Flow Cu Ft	Mean Flow CFS	Total Flow Cu Ft	Mean Flow CFS	Total Flow Cu Ft	Mean Flow CFS
1975	4855	13.3	730	2.0	730	2.0	6643	18.2	10585	29.0
1976	3650	10.0	657	1.8	876	2.4	6059	16.6	9125	25.0
1977	1825	5.0	511	1.4	511	1.4	3616	9.9	4745	13.0
1978	3541	9.7	438	1.2	358	1.0	3984	10.9	5840	16.0
1979	7592	20.8	438	1.2	475	1.3	8978	24.6	10476	28.7
1980	7300	20.0	694	1.9	1445	4.0	9364	25.6	12921	35.4
Average 1975-80	4794	13.1	578	1.6	733	2.0	6441	17.6	8949	24.5
1981	2623	7.2	606	1.7	828	2.3	4698	12.9	6315	17.3

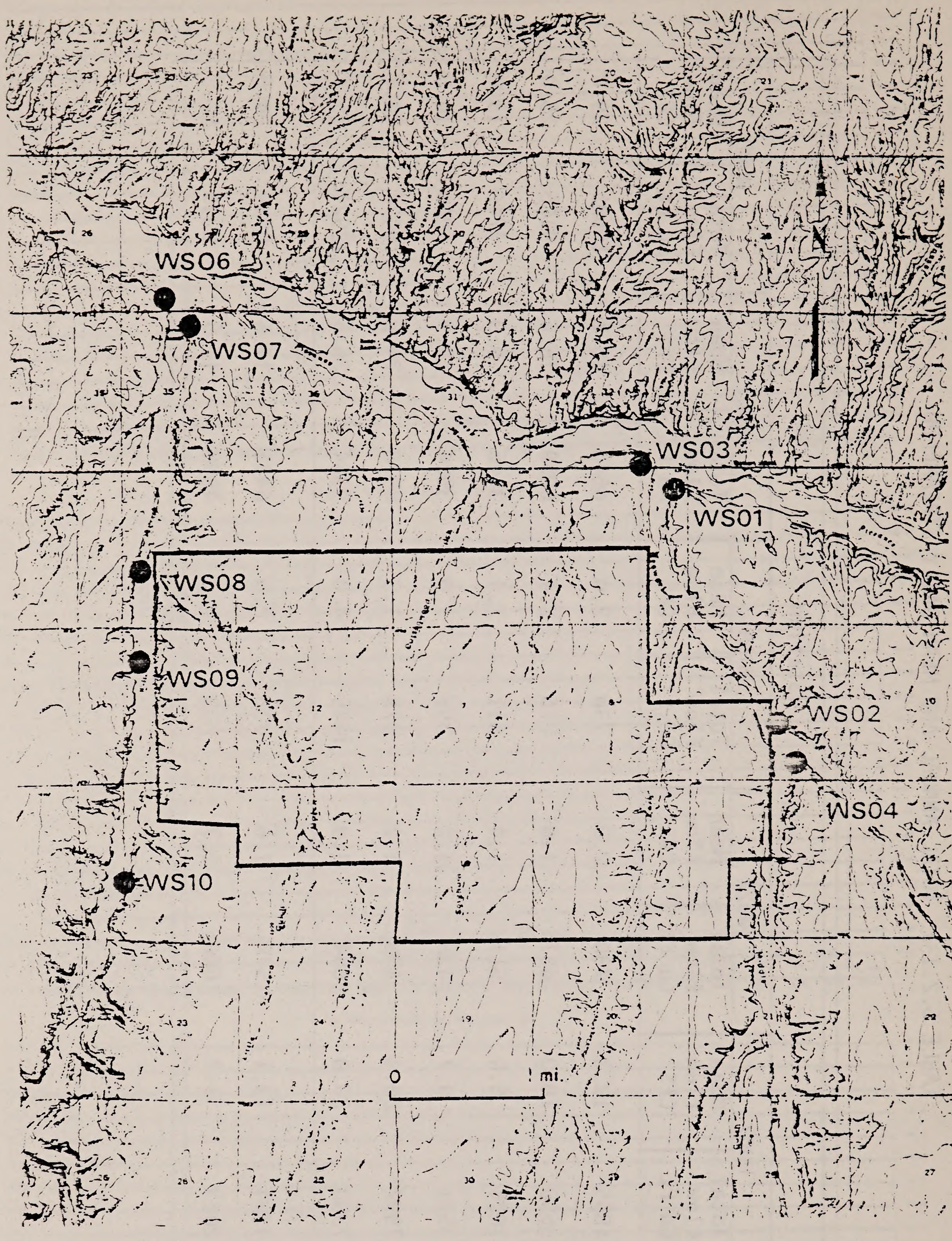


Figure 5.2.2-1

SPRINGS AND SEEPS MONITORING NETWORK
NEAR TRACT

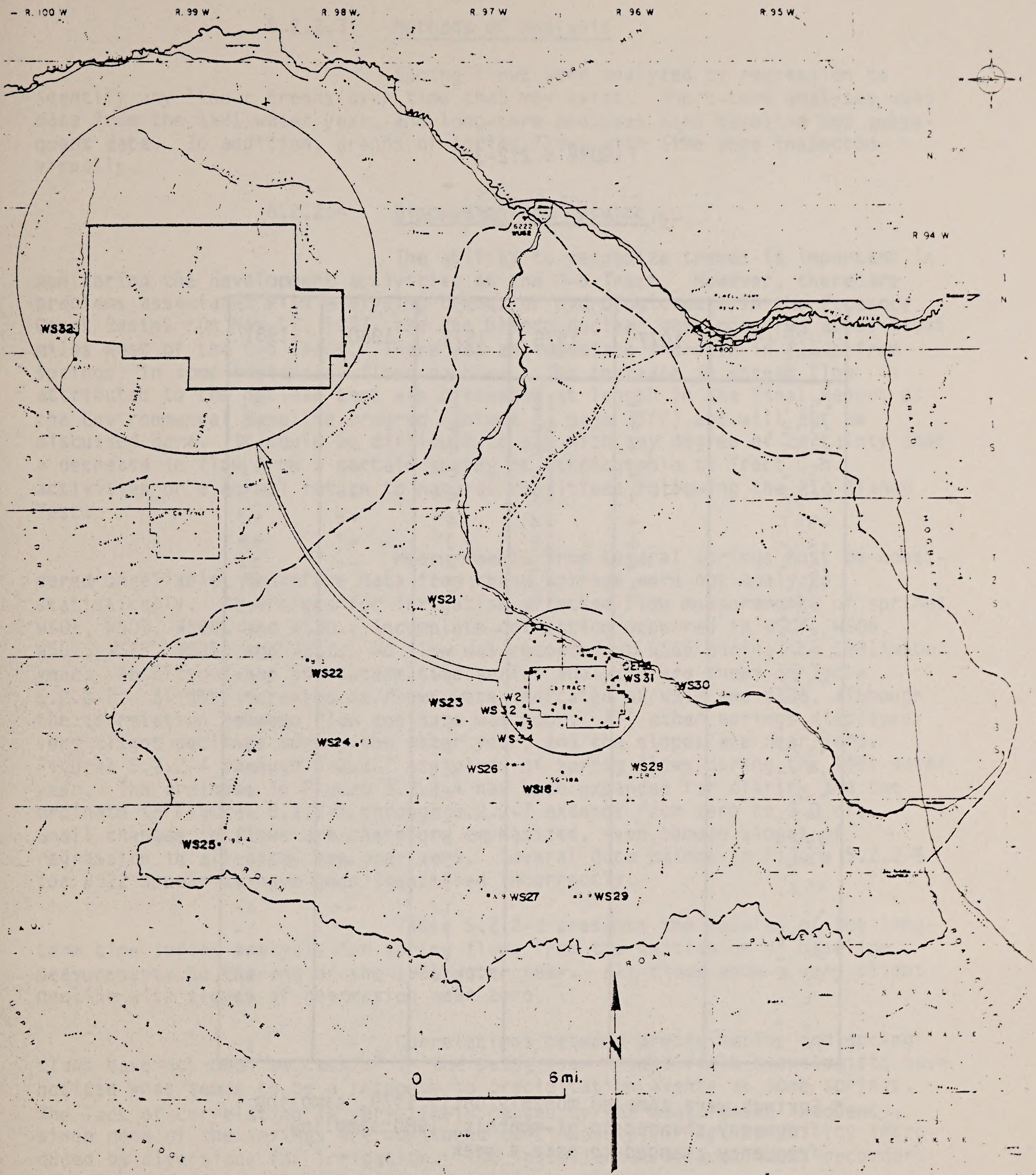


Figure 5.2.2-2
Springs and Seeps Monitoring Network
Off-Tract

FIGURE 5.2.2-3

SPRINGS FLOWS *
SAMPLING TIME INTERVALS

COMPUTER CODE	1977	1978	1979	1980	1981
#S01	4	12	28	[illegible]	51
#S02	4	12	28	[illegible]	51
#S03	4	12	29	[illegible]	[illegible]
#S04	4	12	2[illegible]	[illegible]	51
#S06	4	12	29	4[illegible]	4[illegible]
#S07	4	12	28	42	43
#S08	4	12	30	47	44
#S09	4	12	30	[illegible]	51
#S10	4	12	29	[illegible]	51
#S11				3[illegible]	51
#S12				2[illegible]	4[illegible]
#S21			1[illegible]	[illegible]	4[illegible]
#S22			14	4[illegible]	2[illegible]
#S23			2[illegible]	[illegible]	[illegible]
#S24			2[illegible]	[illegible]	[illegible]
#S25			12	2[illegible]	1[illegible]
#S26			21	47	34
#S27			21	41	34
#S28			20	47	31
#S29			17	32	33
#S30			17	4[illegible]	33
#S31			17	[illegible]	34
#S32			17	[illegible]	34
#S33			17	47	34
#S34			17	4[illegible]	34
#S35			15	[illegible]	2[illegible]
#S36				[illegible]	[illegible]
#S37				1	[illegible]
#S38					1[illegible]

* Springs were sampled monthly until 1979, sampling frequency changed to bi-monthly; 1980 sampling frequency changed to once a week.

Values under year column equal number of samples taken in year.

5.2.2.3 Methods of Analysis

Spring flows were analyzed by regression to identify any linear trends over time that may exist. Short-term analyses used data from the 1981 water year, and long-term analyses used baseline and subsequent data. In addition, graphs of spring flows with time were inspected visually.

5.2.2.4 Discussion and Results

The ability to recognize trends is important in monitoring the development activities on the C-b Tract. However, there are problems associated with analyzing trends or hydrologic data in the Piceance Creek Basin. On May 17, 1973, the Rio Blanco nuclear test occurred about eight miles west of the C-b Tract. There was an immediate increase in flows from springs; in some instances, flows doubled. The increase in stream flow attributed to the nuclear test was discussed at length in the Final Report of the Environmental Baseline Program (Volume 2, page 35ff) and will not be discussed here. It would be difficult to say with any degree of certainty that a decrease in flow from a certain spring is attributable to Tract C-b activities or a normal return to natural conditions following the Rio Blanco Test.

Measurements from several springs must be considered unreliable; therefore data from these springs were not analyzed statistically. Diversions for irrigation affected flow measurements of springs WS01, WS03, WS08, and WS30. Incomplete collection occurred in WS04, WS06, WS07, WS25, WS35, and WS37. No flow was recorded at WS66 during the 1981 water year. Results of the short-term time series analysis are shown on Table 5.2.2-1. Slight increases in flows were indicated at WS12 and WS26, although the correlation between flow and date was poor. All other springs displayed very slight declines during the water year, and the slopes are near zero. Figures 5.2.2-4 through 5.2.2-7 are plots of spring flows during the 1981 water year. The ordinate in Figure 5.2.2-4 has been expanded for clarity and the ordinate in Figures 5.2.2-5 through 5.2.2-7 extends from zero to 3.0 cfs. Small changes in flows are therefore emphasized, even though slopes of regression in all cases are near zero. Several data points in Figure 5.2.2-5 for WS22 appear to have been identified incorrectly.

Table 5.2.2-2 presents the results of the long-term time series analysis for spring flows from the initiation of baseline measurements to the end of the 1981 water year. All flows show a very slight decline with slopes of regression near zero.

Correlations between precipitation and spring flows have not been successful in the past, even though field hydrologists have noticed what seems to be a response to precipitation events at some springs. The lack of correlation is very likely caused by the measurement frequency, since none of the springs are monitored continuously, or by variability introduced by diversions for irrigation. The installation of continuous recorders on selected springs in 1982 will solve this problem.

At the present time, it appears that C-b dewatering and reinjection activity is having no effect on spring flow. The

TABLE 5.2.2-1 SHORT TERM TIME SERIES ANALYSIS FOR FLOW OF SPRINGS DURING WATER YEAR 1981

Spring	Mean Flow (cfs)	Number of Observations	$\hat{\alpha}$	Slope cfs/day	R^2
WS02	0.06	50	0.0001	-0.0002	0.34
WS09	0.19	51	0.0001	-0.00005	0.28
WS10	0.46	51	0.0031	-0.0003	0.16
WS11	0.45	51	0.0001	-0.0004	0.52
WS12	0.28	46	0.0322	0.0001	0.10
WS21	0.40	53	0.0007	-0.0003	0.20
WS22	0.50	39	0.0001	-0.0006	0.87
WS23	1.81	41	0.0001	-0.0051	0.85
WS24	1.10	48	0.0001	-0.0013	0.79
WS26	0.30	45	0.0096	0.0002	0.15
WS27	0.16	45	0.0001	-0.0001	0.63
WS28	1.26	42	0.0007	-0.0011	0.25
WS29	0.06	39	0.0078	-0.0001	0.18
WS31	1.84	44	0.0001	-0.0035	0.94
WS32	0.19	45	0.0001	-0.00005	0.35
WS33	0.76	45	0.0001	-0.0007	0.36
WS34	0.45	45	0.0001	-0.0003	0.80
WS36	1.92	50	0.0001	-0.0020	0.76

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

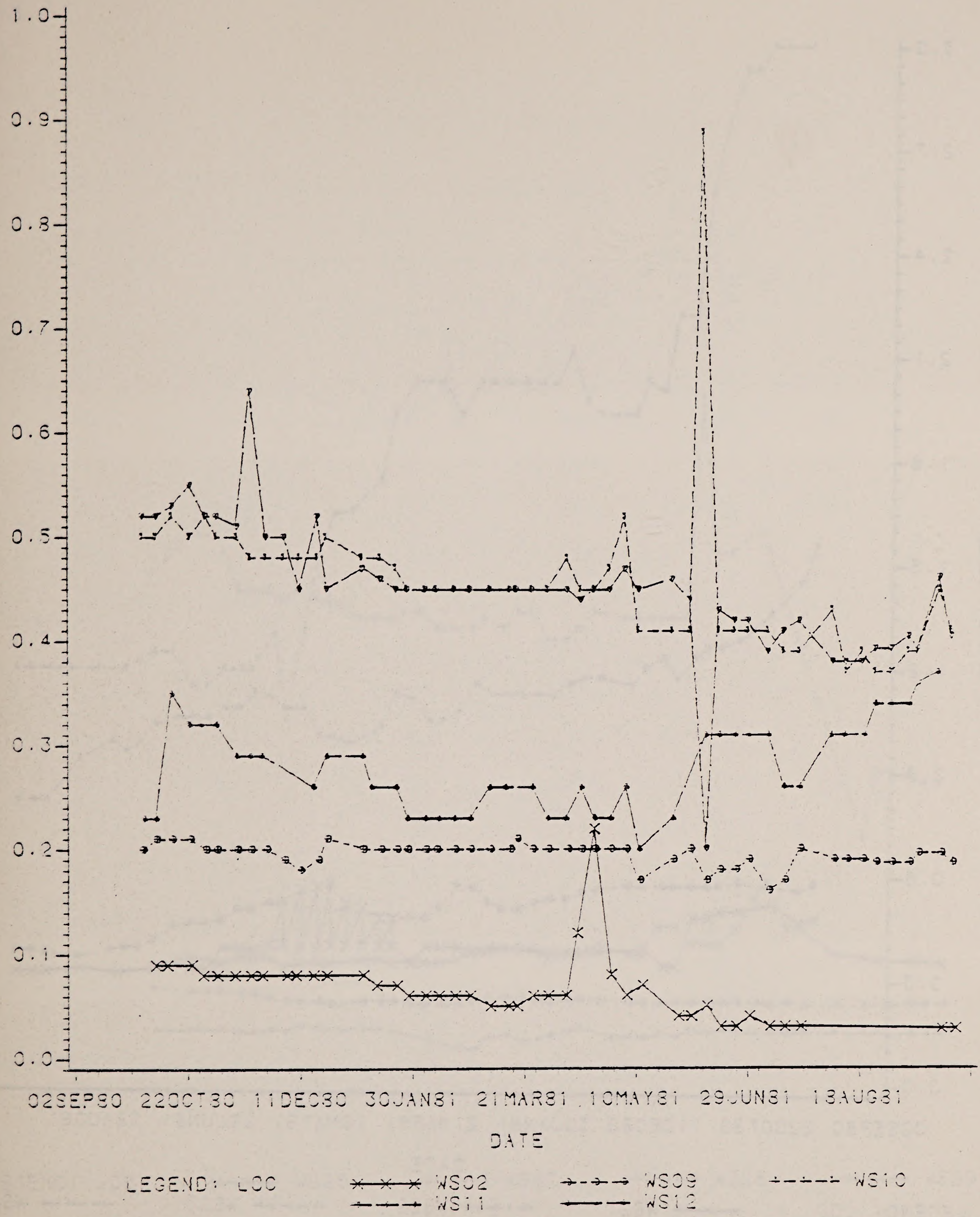


FIGURE 5.2.2-4

SPRING FLOW TIME HISTORY

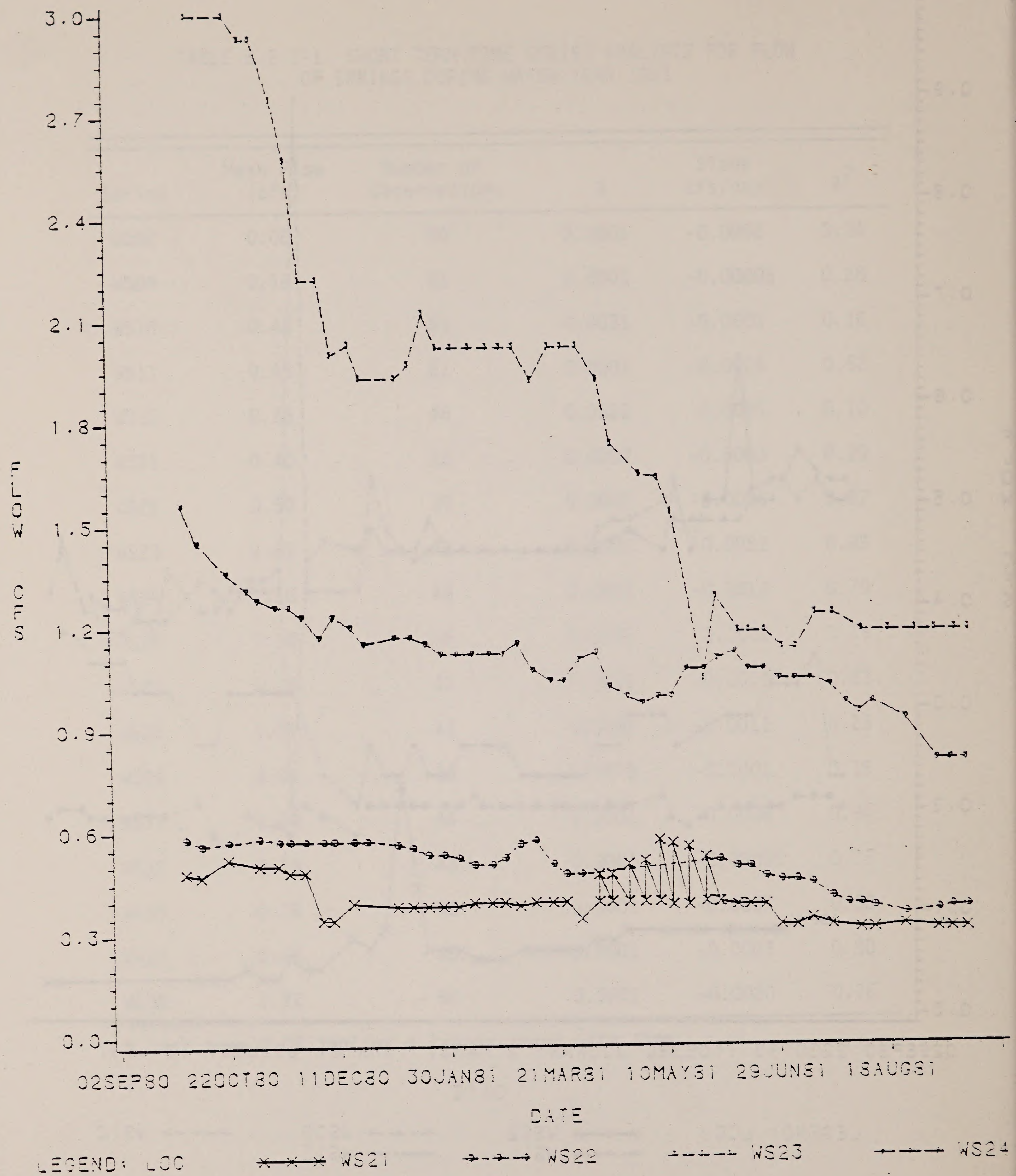


FIGURE 5.2.2-5

SPRING FLOW TIME HISTORY

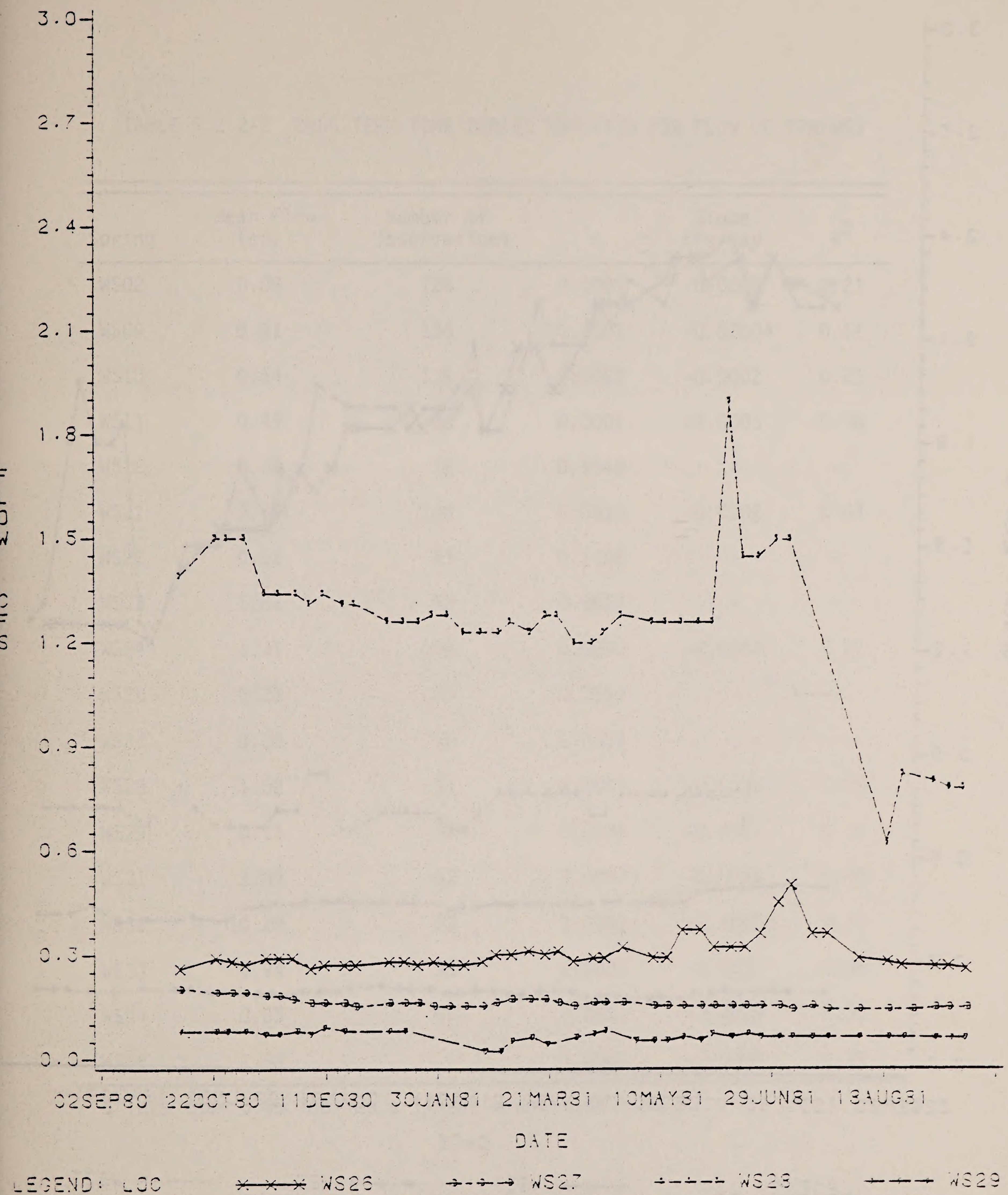


FIGURE 5.2.2-6

SPRING FLOW TIME HISTORY

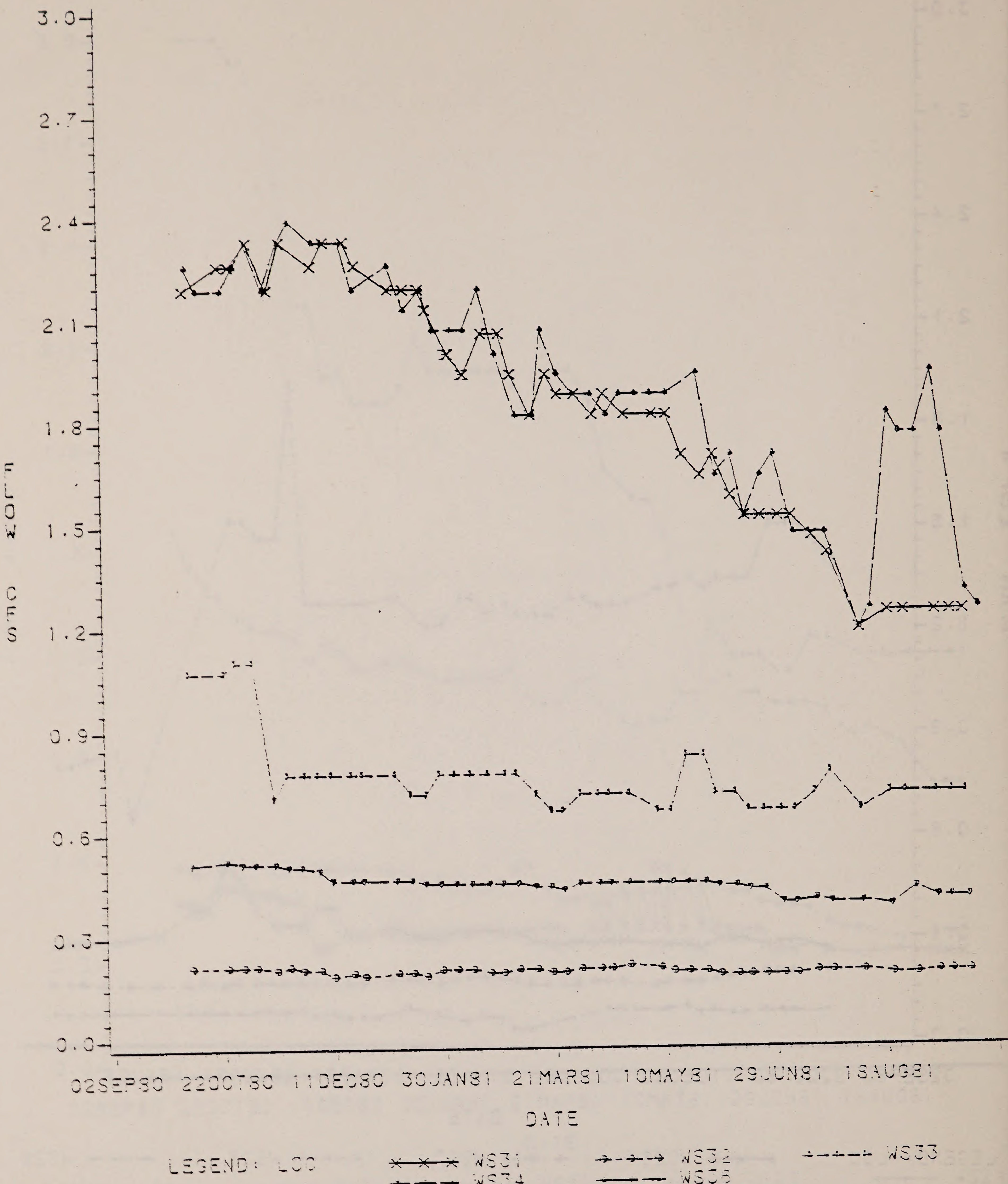


FIGURE 5.2.2-7

SPRING FLOW TIME HISTORY

TABLE 5.2.2-2 LONG TERM TIME SERIES ANALYSIS FOR FLOW OF SPRINGS

Spring	Mean Flow (cfs)	Number of Observations	$\hat{\alpha}$	Slope cfs/day	R^2
WS02	0.09	126	0.0001	-0.0002	0.21
WS09	0.21	136	0.0001	-0.00004	0.11
WS10	0.54	138	0.0001	-0.0002	0.21
WS11	0.49	88	0.0001	-0.0003	0.38
WS12	0.32	72	0.4349	-	-
WS21	0.46	105	0.0313	-0.0002	0.04
WS22	0.52	93	0.1108	-	-
WS23	1.82	98	0.9617	-	-
WS24	1.31	104	0.0003	-0.0003	0.12
WS26	0.33	102	0.7949	-	-
WS27	0.20	96	0.0835	-	-
WS28	1.32	91	0.0001	-0.0003	0.19
WS29	0.11	77	0.0035	-0.0001	0.11
WS31	1.84	97	0.0097	-0.0004	0.07
WS32	10.20	99	0.0001	-0.00003	0.41
WS33	0.94	98	0.0001	-0.0007	0.66
WS34	0.55	99	0.0001	-0.0005	0.91
WS36	1.80		0.0001	-0.0009	0.24

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

variations seen in flows do not form a pattern that can be related either to the reduction in the potentiometric surface from dewatering or the increase in the potentiometric surface during reinjection. Trends appear to be caused by seasonal variation.

5.2.3 Alluvial Wells

5.2.3.1 Scope

Alluvial wells were drilled in all gulches at C-b and in the major drainages of Piceance Creek, Willow Creek, and Stewart Gulch. These wells were sampled during the baseline period and will be used to monitor the alluvial aquifers during the development of the C-b Tract. The locations of the alluvial wells are shown on Figure 5.2.3-1 and Table 5.2.3-1 provide the time intervals for water level measurements.

5.2.3.2 Objectives

Monitoring of water levels in the alluvial wells is designed to detect seepage from the main dumps in Cottonwood or Sorghum Gulches, to detect leakage from any proposed water storage dams, to monitor any water that may enter the system through accidental spills or runoff from construction areas, and to verify the lack of communication with bedrock aquifers.

5.2.3.3 Experimental Design

Monthly measurements of water levels in the alluvial wells were continued during 1981 as indicated on Table 5.2.3-1. Data from these measurements were subjected to the methods described in Section 5.2.3.4.

5.2.3.4 Methods of Analysis

A linear regression model was used to determine the existence of both short- or long-term time trends in the alluvial well levels measurements. Time series plots of the water levels in each well were prepared and qualitatively analyzed. In addition, plots of alluvial wells and companion bedrock aquifer wells were prepared for qualitative comparison. These plots were presented as Figures 5.1-1 and 5.1-2.

5.2.3.5 Discussion and Results

Time series plots of water levels for the 1981 water year are shown on Figure 5.2.3-2. Results of the linear regression model for short-term time series analysis are presented in Table 5.2.3-2. Alluvial well WA02 exhibited a slight negative linear trend and WA12 displayed a slight positive trend. All other alluvial wells indicated no linear trends in the short term analysis of data from water year 1981. The long-term time series analysis results are shown in Table 5.2.3-3. Three wells indicated downward linear trends; these were WA03, WA09, and WA10. Two wells, WA01 and WA05 showed upward linear trends. In all indications of trends, slopes were near zero. WA04, WA10, and WA13 remained dry during water year 1981. Water

Figure 5.2.3-1
Alluvial Aquifer Monitoring Network

TABLE 5.2.3-1

ALLUVIAL WELLS *

SAMPLING TIME INTERVALS

FOR LEVELS

COMPUTER CODE	1974	1975	1976	1977	1978	1979	1980	1981
WA01	3	9	12	12	12	[illegible]	11	12
WA02	3	9	12	12	12	7	12	12
WA03	3	9	12	12	12	7	12	11
WA04	3	9	12	12	12	7	9	9
WA05	3	9	12	12	12	5	12	11
WA06	3	9	12	12	12	[illegible]	11	11
WA07	4	9	12	12	12	[illegible]	10	11
WA08	3	9	12	12	12	7	14	10
WA09	3	[illegible]	12	12	12	7	13	12
WA10	3	9	12	12	12	7	8	11
WA11	3	9	12	12	12	[illegible]	[illegible]	[illegible]
WA12	3	9	12	12	12	7	12	12
WA13	3	9	12	12	12	[illegible]	7	10
WA55						1	8	9
WA56							3	10

* ALLUVIAL WELLS ARE SAMPLED MONTHLY, THEREFORE, VALUES UNDER YEAR COLUMN EQUAL NUMBER OF SAMPLES TAKEN IN YEAR.

FIGURE 5.2.3-2

TIME SERIES FOR ALLUVIAL WELLS

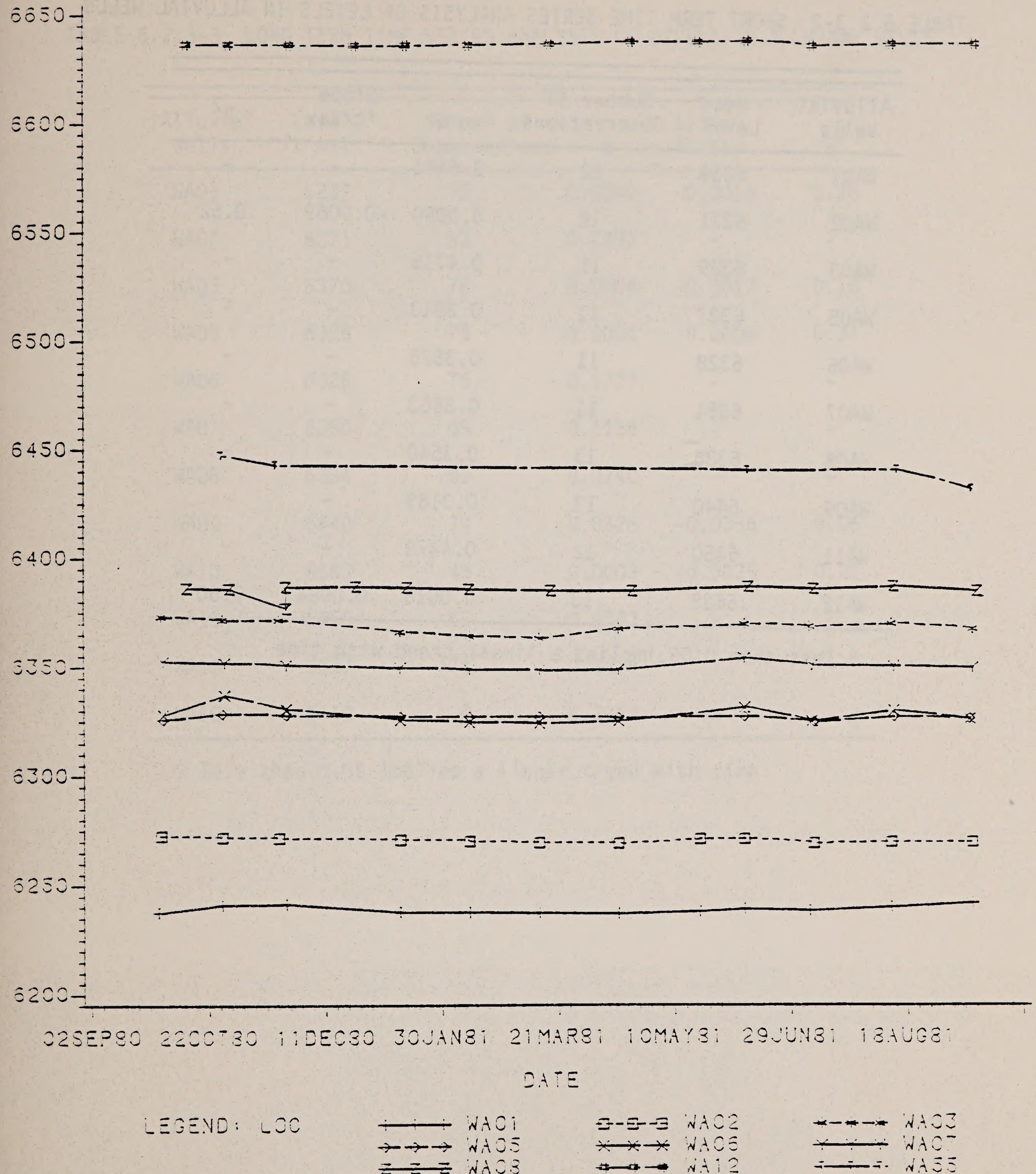


TABLE 5.2.3-2 SHORT TERM TIME SERIES ANALYSIS OF LEVELS IN ALLUVIAL WELLS

Alluvial Wells	Mean Level	Number of Observations	$\hat{\alpha}$	Slope ft/day	R^2
WA01	6239	12	0.6441	-	-
WA02	6271	12	0.0080	-0.0069	0.52
WA03	6369	11	0.4716	-	-
WA05	6327	11	0.3913	-	-
WA06	6328	11	0.3876	-	-
WA07	6351	11	0.8663	-	-
WA08	6386	13	0.3540	-	-
WA09	6440	13	0.3189	-	-
WA11	6450	12	0.4478	-	-
WA12	6638	13	0.0018	0.0084	0.60

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

TABLE 5.2.3-3 LONG TERM TIME SERIES ANALYSIS OF LEVELS IN ALLUVIAL WELLS

Alluvial Wells	Level ft msl	Number of Observations	$\hat{\alpha}$	Slope ft/day	R^2
WA01	6237	72	0.0001	0.0016	0.26
WA02	6271	53	0.2893	-	-
WA03	6370	76	0.0004	-0.0017	0.16
WA05	6326	73	0.0001	0.0008	0.31
WA06	6328	75	0.1727	-	-
WA07	6350	65	0.1156	-	-
WA08	6384	69	0.0740	-	-
WA09	6440	74	0.0328	-0.0356	0.06
WA10	6563	45	0.0003	-0.0035	0.27
WA11	6450	65	0.0593	-	-
WA12	6637	71	0.6428	-	-
WA55	6440	8	0.8863	-	-

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

levels in the alluvial wells do not appear to be affected by activities on the C-b Tract, including the reinjection test discussed in Section 5.2.6.

5.2.4 Remote Off-Tract Bedrock Wells

5.2.4.1 Scope

Remote off-Tract bedrock wells include all the wells monitoring water in the bedrock except for two wells near the northern Tract boundary (SG-19 and SG-20), and two wells south of the Tract (SG-18 and SG-21). SG-18 is almost two miles south of the Tract, but it is monitored with and at the same frequency as the on-Tract wells. All the wells referred to in this Section are completed as either Upper Aquifer Wells (WX), Lower Aquifer Wells (WY), or are composite wells open to both intervals (WV), as in the older U.S.G.S. system.

North of Piceance Creek, three wells monitor the Upper Aquifer (WX64, WX67 and WX69) and four wells monitor the Lower Aquifer (WY64, WY67, WY68 and WY69). East of the C-b Tract, the two monitoring wells (WV02 and WV03) are open to both Upper and Lower Aquifers. Southeast and south of the Tract, WX73 and WX75 monitor the Upper Aquifer; WY75, WY76 and WY77 monitor the Lower Aquifer; and WV04 and WV05 are open to both. Three of these wells (WY76, WY77 and WV05) were flowing during the 1981 water year. Southwest and west of the Tract, WX71 and WX72 monitor the Upper Aquifer, and the Lower Aquifer is monitored by WY70, WY71 and WY72. West and northwest of the Tract, WX65 monitors the Upper Aquifer; WY65, WY66 and WY79 monitor the Lower Aquifer and WV01 is open to both aquifers. WY66 was flowing during the 1981 water year. Locations of all these wells are shown on Figure 5.2.4-1.

5.2.4.2 Objectives

The basic objective in monitoring remote off-Tract bedrock wells is to obtain data for the interpretation of the subsurface geohydrology and to determine the distance and magnitude of the influnce that shaft dewatering and reinjection activities may have on the Upper and Lower Aquifers.

5.2.4.3 Experimental Design

The sampling frequency for levels is shown on Table 5.2.4-1. Samples are taken in eight Upper Aquifer wells, 14 Lower Aquifer wells, and eight composite wells open to both aquifers. These samples were obtained on a monthly basis during the 1981 water year.

5.2.4.4 Methods of Analysis

Data were analyzed by the application of a linear regression model to determine the existence of both short- or long-term time trends in the water levels of the remote off-Tract bedrock wells. In addition, time series plots were prepared for qualitative analysis and comparisons.

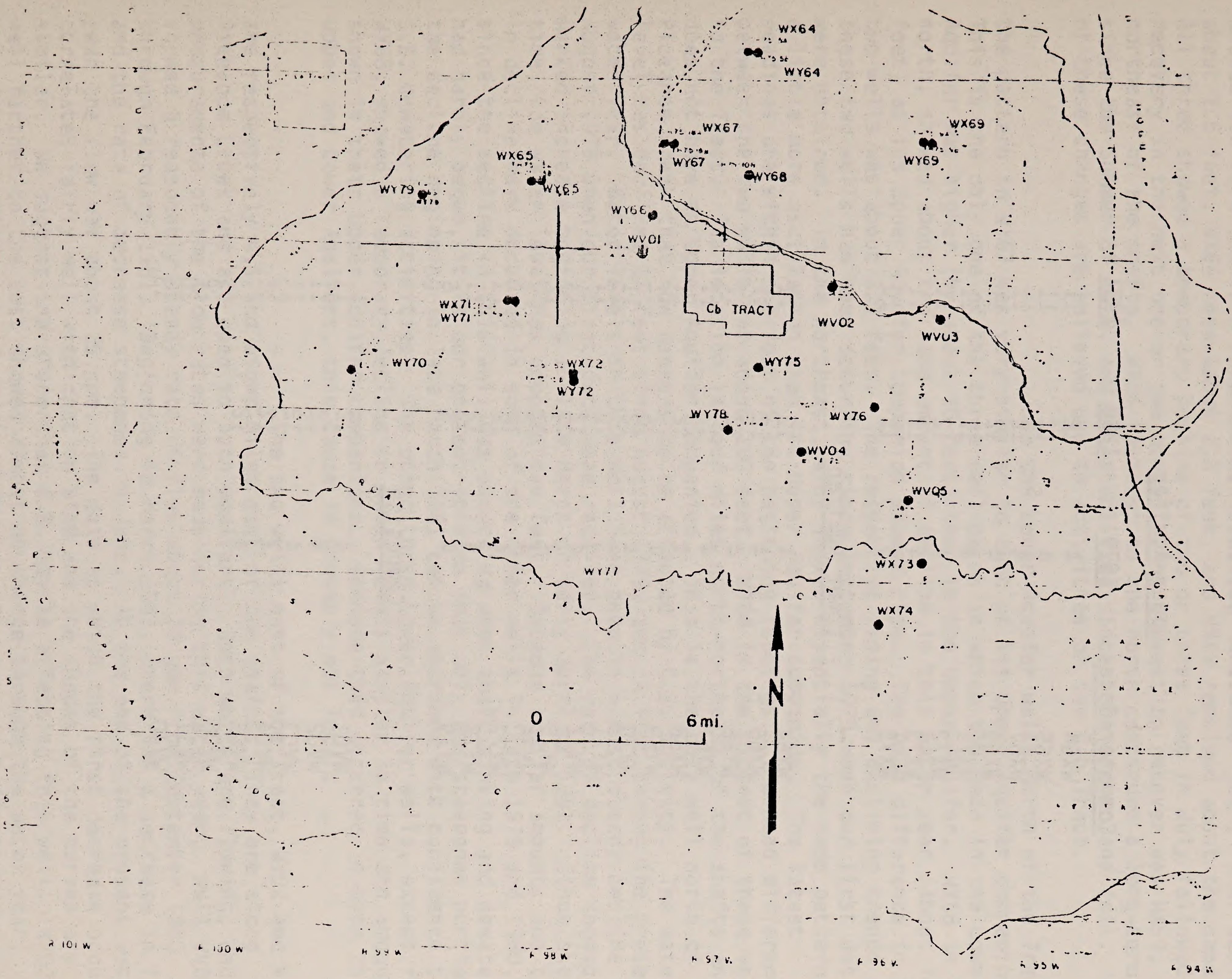


Figure 5.2.4-1
Deep Well Monitoring Network Off-Tract

TABLE 5.2.4-1

REMOTE OFF-TRACT BEDROCK WELLS
SAMPLING FREQUENCY FOR LEVELS

Upper Aquifer

Computer Code	1979	1980	1981
WX64	4	12	11
WX65	4	12	11
WX67	4	12	11
WX69	4	12	11
WX71	4	12	11
WX72	4	12	11
WX73	4	12	11
WX75	3	12	10
Lower Aquifer			
WY64	4	12	11
WY65	4	12	11
WY66	4	12	11
WY67	4	12	11
WY68	4	12	11
WY69	4	12	11
WY70	4	12	11
WY71	3	12	11
WY72	4	12	11
WY75	4	12	12
WY76	4	12	11
WY77	4	12	11
WY78	4	12	11
WY79	4	8	5
Composite			
WV01	4	12	11
WV02	4	12	11
WV03	4	12	11
WV04	4	12	11
WV05	4	12	11
WV06			5
WV37			20
WV40			13

5.2.4.5 Discussion and Results

The Upper Aquifer wells north of Piceance Creek showed not more than 2.5 feet of change during this water year. WX67 declined about 1.5 feet, WX64 rose about 2.5 feet, and WX69 remained about the same. All three showed a temporary decline of two or three feet in July followed by recovery in the next one or two months. The slowest to recover was WX59, northeast of the shafts. WX64 farthest to the north continued a long-term rise since the Summer of 1979, and has stabilized since late summer and fall. None of these changes are believed due to activities on the C-b Tract.

In the Lower Aquifer wells north of the Tract, the pattern in WY67 was very similar to that of its Upper Aquifer companion. This is the only one of the three well pairs in which the head in the Lower Aquifer was higher (by about 20 feet) than in the Upper Aquifer. WY68 in the north, showed about the same amount of decline in this water year (about four feet) as its Upper Aquifer companion showed rise. The head difference in the two wells was about 325 feet. The respective rising and declining trends in these two wells has been occurring since September 1979 when our first data were obtained. In the northeast, WY69 showed essentially the same pattern with a little more oscillation than its Upper Aquifer companion. The latest readings are within one foot of the beginning readings. The head difference between the two wells was about 100 feet. WY68 is the closest of these wells to the Tract. Its location is four miles north-northeast of the shafts and does not have an Upper Aquifer companion. This is the only well north of Piceance Creek that now appears to be affected by C.B. activity. The water level has declined 17 feet since August 1979, and 14 feet during the present water year. Water levels in this well have been in almost steady decline since August 1979 when our first data were received. The rate of decline showed a marked increase beginning in late March or early April of 1981. Since that time, the water level has dropped ten feet. Because similar amounts and trends in decline have occurred in some of the other wells in late 1979 and 1980, and since the decline in this well was occurring when shaft sinking and dewatering had hardly begun, it is our present opinion that only the steepened portion of the decline beginning in late March 1981 can be ascribed with confidence to C.B. dewatering activities. The other three Lower Aquifer wells, except for WY68, showed a temporary decline in water levels similar in time and amount as shown in their Upper Aquifer companions. Because this occurred in both the Upper and Lower Aquifers, this cause is probably not local.

The two wells east of the Tract, WV02 and WV03, are respectively 4.5 and eight miles east of the shafts. They are along Piceance Creek and are open to both aquifers. Both wells are flowing, and measurements of the flow rates were made during this water year. Well WV02 showed a reasonably steady rate of flow about 29 gpm from September 1980 through February 1981. Beginning in March 1981, there was a decrease in flow, and the rate of decrease steepened in June. At the end of the present water year the flow was about 25 gpm. The date at which the first decrease occurred correlates fairly well with that in WY68 and the shapes of the curves are similar. We suggest therefore that C.B. may be affecting this well. WV03, the well farther to the east showed almost no change through the water year, maintaining a flow rate of about eight gpm with very minor fluctuations in both directions. It may be significant that a sharp temporary drop in flow rate

occurred in WV02 in June at the same time that the temporary declines in water levels are observed in the wells north of Piceance Creek. A very slight negative oscillation also occurred at that time in WV03, but this may not have exceeded measurement error.

Two of the wells southeast and south of the C-b Tract were flowing during the 1981 water year. These wells, WY76 and WV05 respectively are Lower Aquifer and composite completions. None of the seven wells showed significant change during the water year. There was very slight decline within the last four months in WX75 closest to the Tract, and in WX73 farthest from the Tract in Parachute Creek. Because of the response in WX73, we doubt that the slight decline in WX75 is due to mine dewatering. WY77 is 11 miles south of the Tract at the crest of the Roan Plateau. This well flows at about six gpm. The flow rate ranged from a high of 7.2 gpm in December 1980 to a low of 5.5 gpm in November 1980, August 1981, and October 1981. A slight decline began at the high in December 1980 and continued with fluctuations to the end of the water year. As with the slight decline in WX73, we do not believe this can be attributed to dewatering activities so far from the shafts. In the wells southeast and south of the Tract there is no clear evidence of the temporary summer drop in water levels seen in the wells north of Piceance Creek.

There are five wells southwest of the Tract; two are Upper Aquifer wells and three are Lower Aquifer wells. One of these is flowing and none appeared to have been affected by C.B. activities during the 1981 water year. WX72 and WY72 are a pair six miles southwest of the shafts. Of these, the Lower Aquifer has the higher head (about 15 feet). Both wells showed a very similar pattern beginning with the first available data in August 1979. The levels rose irregularly about three feet by Summer 1980 then slowly and steadily declined about two feet. In September and October of 1981, they appear to have stabilized at or slightly above the Summer 1979 levels. Both of these wells show a short term drop of about two feet in July 1981. WX71 and WY71 are a pair six miles west of the Tract. WY71 shows an extremely slight decline through this water year, not more than 1.5 feet. It does not show the June/July 1981 temporary decline. WX71 flowed intermittently during the present water year, ranging irregularly from no flow to about 1.3 gpm. This well was pumped for livestock water in Summer 1981, during which it did not flow when idle. Very slight flow began again in October 1981. WY70, in upper Black Sulphur Creek, is the most remote well to the southwest of the Tract, 13 miles from the shafts. This well has shown rising levels from our beginning observations in February 1980. Since that time it has risen twelve feet. During the present water year it has risen about four feet. Although this well is not far from a steam injection project, the cause is not yet clear. A similar pattern and amount of rise was seen in WX64, eight miles north of the shafts and about eighteen miles from the injection project. Rising levels were also seen in some wells southeast of the Tract. Most of the wells showing consistently rising water levels are in the higher parts of the drainage basin. WY70 showed a slight but perceptible drop in water level in July 1980.

Five wells are located north-northwest of the Tract. The nearest are WV01 and WY66 about three miles northwest of the shafts; WX65 and WY65, a pair six miles northwest of the shafts; and WY79, ten miles west northwest of the shafts. WV01 showed a decline of about five feet since baseline, beginning in October 1980 and leveling off in the summer of the

present water year. The October 1981 reading showed a slight rise in water level. WY66 is a flowing well showing almost a constant rate at about 0.5 gpm beginning in April 1981. Prior to that time the well was reported as flowing but without measurements of the rate. It is significant that a period of no flow appears to have occurred from April through June 1980. As reported in a letter from Jex-Piland dated June 17, 1981, periods of no flow were observed on April 11, 1978 and September 21, 1978. It is important that periods of no flow occurred in this well as long ago as 1978. Given the early sporadic activity of WY66, it is too soon to attribute the effects in this well and in the Mobil wells to C.B. activity. The head in the Upper Aquifer well WX65 is about 20 feet higher than in the Lower Aquifer well WY65. Both wells showed very slight general decline through the present water year but with some rising levels, the largest being in WX65, the Upper Aquifer well. Both wells showed a drop of about two feet in July. WY79 is 11 miles west northwest of the shafts. It is the westernmost of the C.B. monitoring wells and about a mile from the drainage divide between Piceance Creek and Yellow Creek. This well is only five miles from the center of the C-a Tract. Because of difficulty in measurement, we have begun to receive regular data only since late June, 1981. The June through September readings varied not more than one foot, but the October 1981 reading showed a marked drop of four feet. All of these readings are about 45 feet lower than a single reading made in February 1980. Because this well is not far from the C-a Tract, it may in time be affected by C-a activity. However, the well is also used for short periods of time by hunting parties and for stock watering, and this is very likely the reason for the sharp drop in the October reading.

Results of the short-term and long-term linear regression analyses for the levels in upper aquifer, lower aquifer, and composite wells are provided on Tables 5.2.4-2 and 5.2.4-3. Composite time series plots of levels from remote off-Tract bedrock wells for the 1981 water year are shown as Figures 5.2.4-2, 5.2.4-3 and 5.2.4-4.

5.2.4.6 Summary

North of Piceance Creek, only WY68 shows evidence of effect from C.B. dewatering activity. The water level in this well has been declining since the beginning of observation in March 1981. The amount of decline that we believe results from C.B. activity is ten feet, beginning with a marked increase in the rate of decline in late March or early April, 1981.

East of the Tract, a drop in flow rate of about four gpm suggests that WV02 may be becoming affected, four and one-half miles up Piceance Creek from the shafts. No effects have reached WV03 located eight miles up Piceance Creek from the shafts.

No effects attributed to C.B. activities were seen in the wells southeast and south of the Tract.

No effects attributed to C.B. activities were seen in the wells west and southwest of the Tract. Of this group, WY70 in upper Black Sulphur Creek and 13 miles from the Tract continued to show rising water levels as in the previous water year.

TABLE 5.2.4-2 SHORT TERM TIME TREND ANALYSIS OF WATER LEVELS IN REMOTE OFF-TRACT UPPER AQUIFER, LOWER AQUIFER, AND COMPOSITE WELLS

Bedrock Wells	Mean Level	Number of Observations	$\hat{\alpha}$	Slope ft/day	R^2
WX64	6737	12	0.5632	-	-
WX65	6331	12	0.0003	-0.0119	0.74
WX67	6308	12	0.0156	-0.0042	0.46
WX69	6898	12	0.3368	-	-
WY64	6441	12	0.0002	-0.0114	0.76
WY65	6312	12	0.5195	-	-
WY67	6235	12	0.0282	-0.0039	0.40
WY68	6503	12	0.0001	-0.0315	0.92
WY69	6885	12	0.9071	-	-
WY70	6956	12	0.0001	0.0110	0.88
WV01	6332	12	0.0001	-0.0154	0.97
WV05	7358	12	0.7533	-	-

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

TABLE 5.2.4-3 LONG TERM TIME TREND ANALYSIS OF WATER LEVELS IN REMOTE OFF-TRACT UPPER AQUIFER, LOWER AQUIFER, AND COMPOSITE WELLS

Bedrock Wells	Mean Level	Number of Observations	$\hat{\alpha}$	Slope ft/day	R^2
WX63	6550	58	0.0001	-0.0170	0.55
WX64	6762	27	0.0001	0.0086	0.51
WX65	6332	27	0.0009	-0.0033	0.36
WX67	6308	27	0.0108	-0.0014	0.23
WX69	6897	27	0.1025	-	-
WY61	6493	43	0.5415	-	-
WY62	6509	60	0.0001	-0.0152	0.27
WY64	6441	27	0.5626	-	-
WY65	6312	27	0.0016	-0.0018	0.33
WY67	6325	27	0.0001	-0.0021	0.64
WY68	6505	27	0.0001	-0.0207	0.84
WY69	6891	27	0.0820	-	-
WY70	6954	22	0.0001	0.0149	0.87
WV01	6333	27	0.0001	-0.0063	0.71
WV05	7356	26	0.1215	-	-

$\hat{\alpha}$ less than 0.05 implies a linear trend with time

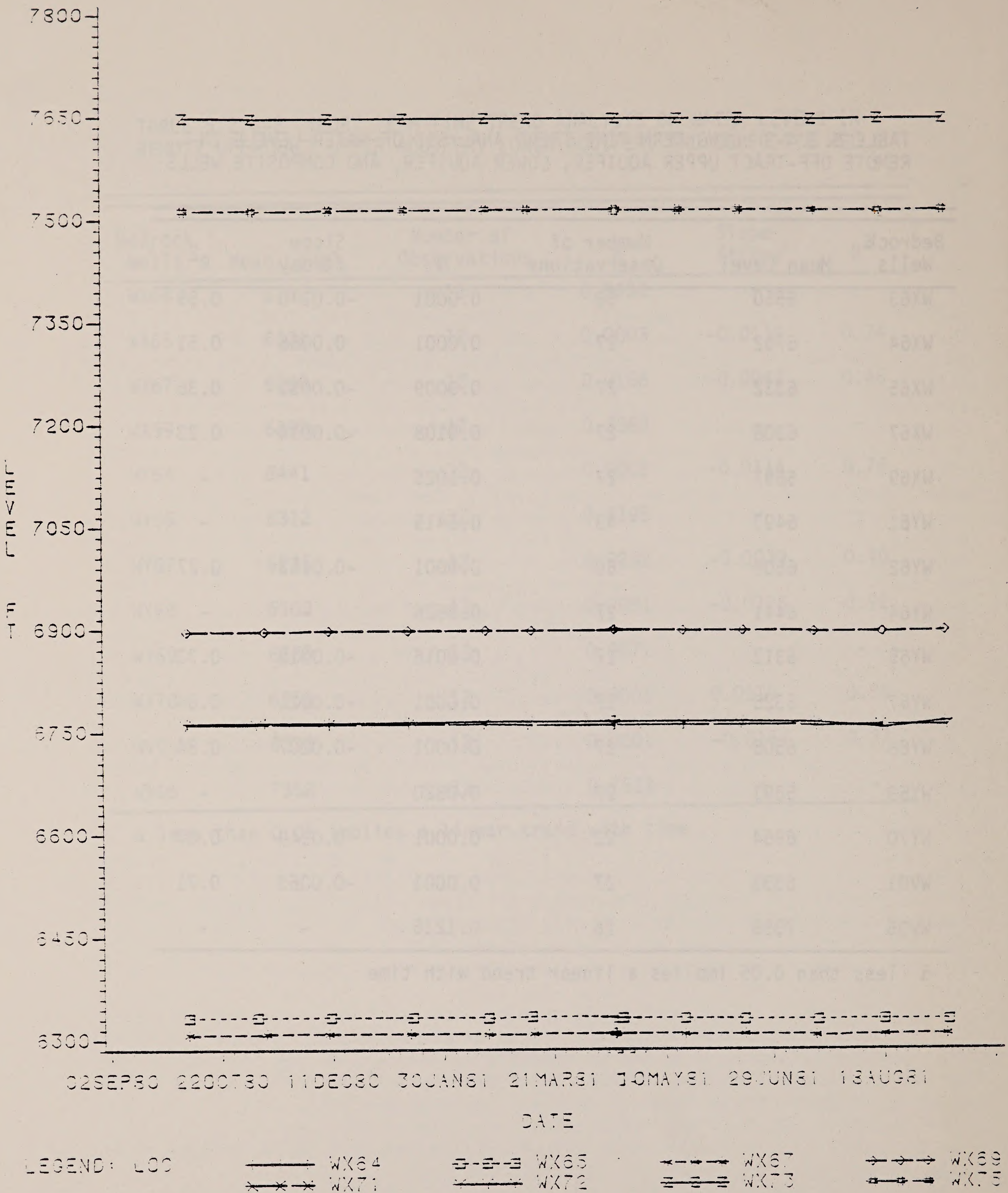


FIGURE 5.2.4-2

Water Levels in Remote Off-Tract Upper Aquifer Wells

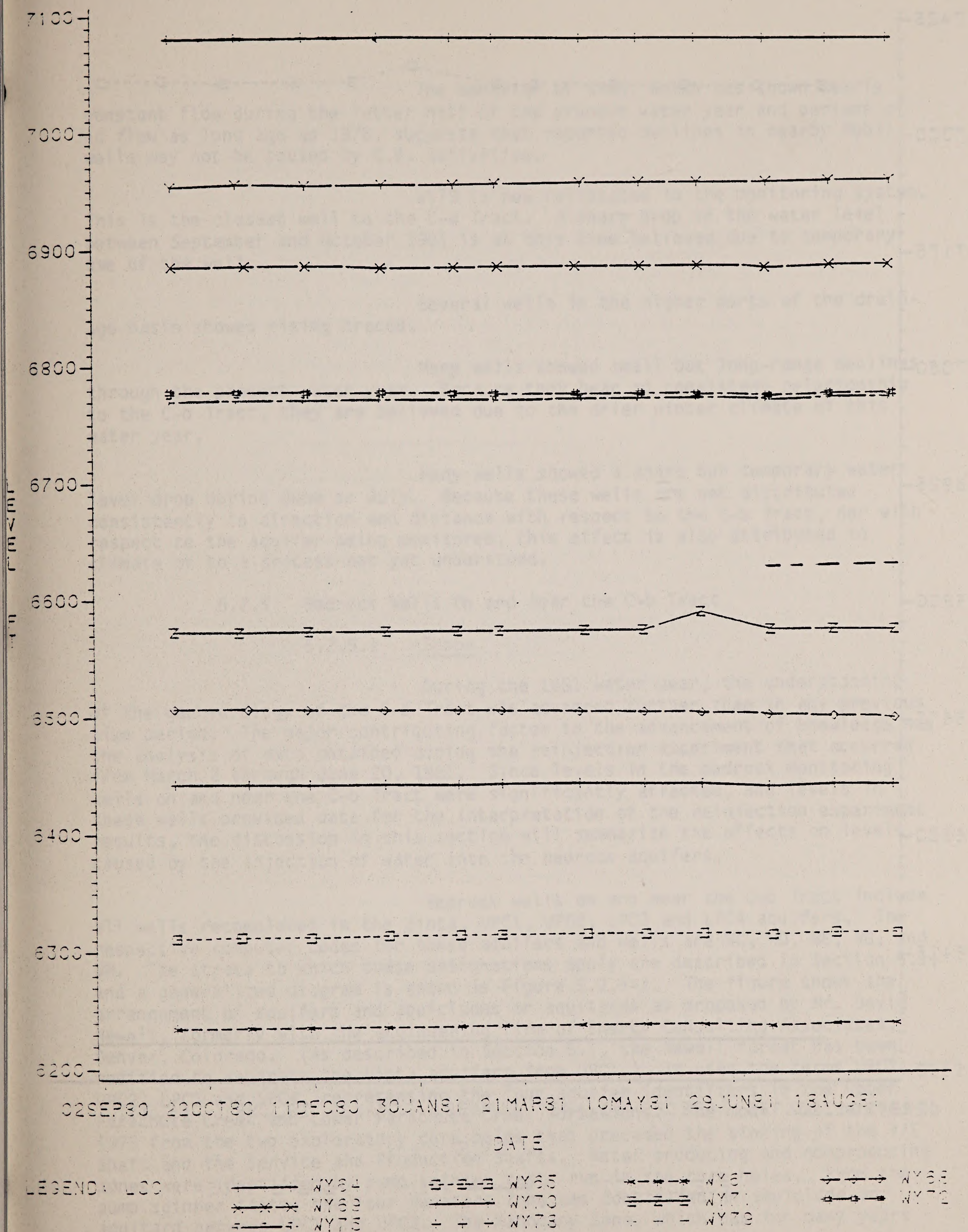


FIGURE 5.2.4-3

Water Levels in Remote Off-Tract Lower Aquifer Wells

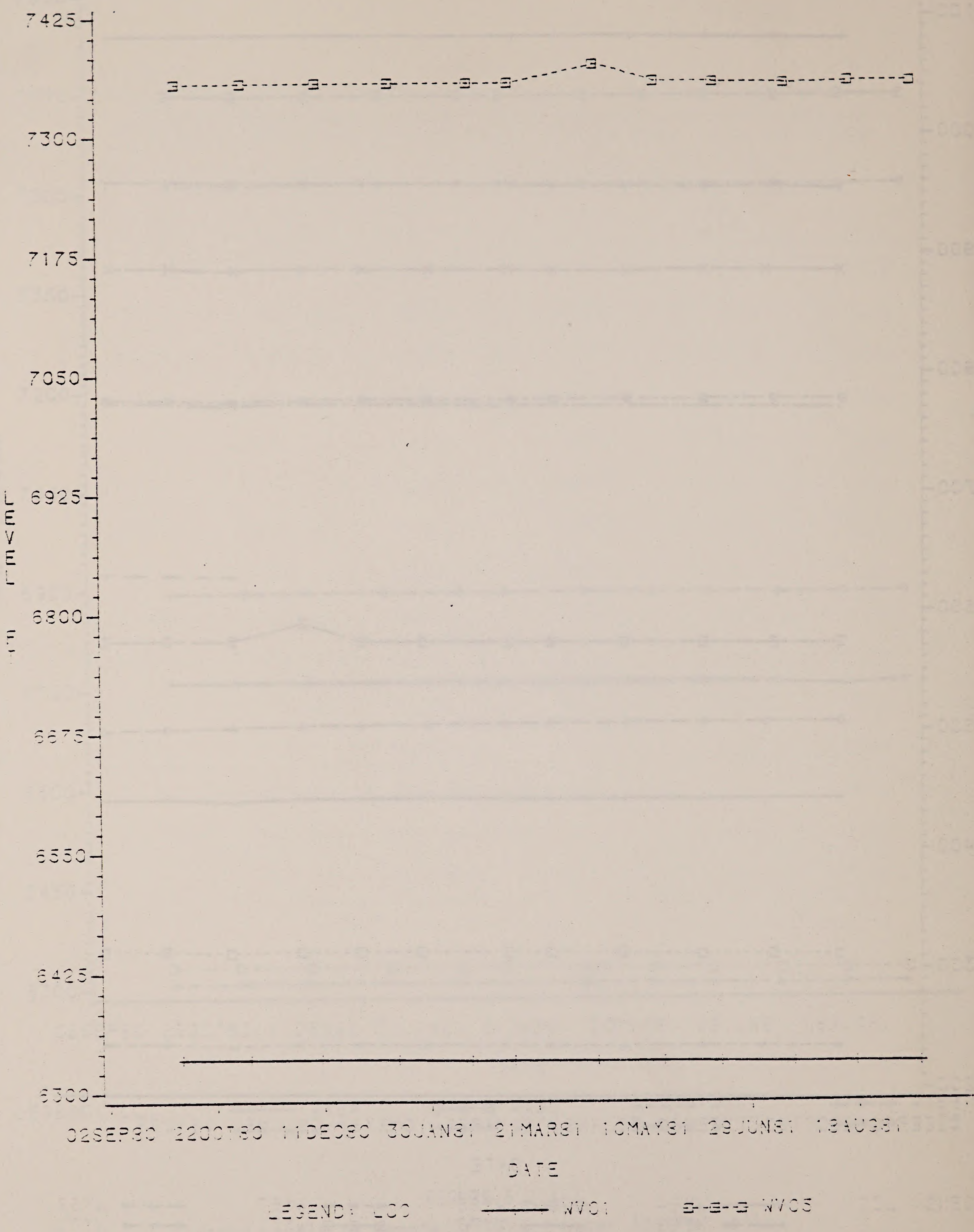


FIGURE 5.2.4-4

Water Levels in Remote Composite Wells

The behavior of WY66, which has shown nearly constant flow during the latter half of the present water year and periods of no flow as long ago as 1978, suggests that reported declines in nearby Mobil wells may not be caused by C.B. activities.

WY79 is now reinstated in the monitoring system. This is the closest well to the C-a Tract. A sharp drop in the water level between September and October 1981 is at this time believed due to temporary use of the well.

Several wells in the higher parts of the drainage basin showed rising trends.

Many wells showed small but long-range declines through the present water year. Because they bear no consistent relationship to the C-b Tract, they are believed due to the drier winter climate of this water year.

Many wells showed a sharp but temporary water level drop during June or July. Because these wells are not distributed consistently in direction and distance with respect to the C-b Tract, nor with respect to the aquifer being monitored, this effect is also attributed to climate or to a process not yet understood.

5.2.5 Bedrock Wells On and Near the C-b Tract

5.2.5.1 Scope

During the 1981 water year, the understanding of the geohydrology of the C-b Tract was advanced further than in any previous time period. The major contributing factor to the advancement of knowledge was the analysis of data obtained during the reinjection experiment that occurred from March 2 through June 20, 1981. Since levels in the bedrock monitoring wells on and near the C-b Tract were significantly affected, and levels in these wells provided data for the interpretation of the reinjection experiment results, the discussion in this section will summarize the effects on levels caused by the injection of water into the bedrock aquifers.

Bedrock wells on and near the C-b Tract include all wells recompleted in the Uinta, UPC1, UPC2, LPC3 and LPC4 aquifers. The respective computer codes for these aquifers and wells are WC, WD, WE, WG, and WH. The strata to which these designations apply are described in Section 5.1, and a generalized diagram is shown as Figure 5.2.5-1. The figure shows the arrangement of aquifers and aquicludes or aquitards as proposed by Mr. David Newell, formerly with the engineering firm of Energy Consulting Associates, Denver, Colorado. (As described in Section 5.1, the Newell format has been modified to separate the Uinta aquifers from UPC1.) It uses the terms UPC1, UPC2, LPC3 and LPC4, representing the four aquifer identifiers in the Upper Parachute Creek and Lower Parachute Creek Formations. The model was derived in 1978 from the two exploratory core holes that preceded the sinking of the V/E Shaft and the Service and Production Shafts. Water producing and nonproducing zones were identified by pump spinner tests run in the core holes. From the pump spinner tests, the Four Senators Zone was considered an aquiclude or aquitard between UPC1 and UPC2. The Mahogany Zone, which has for many years

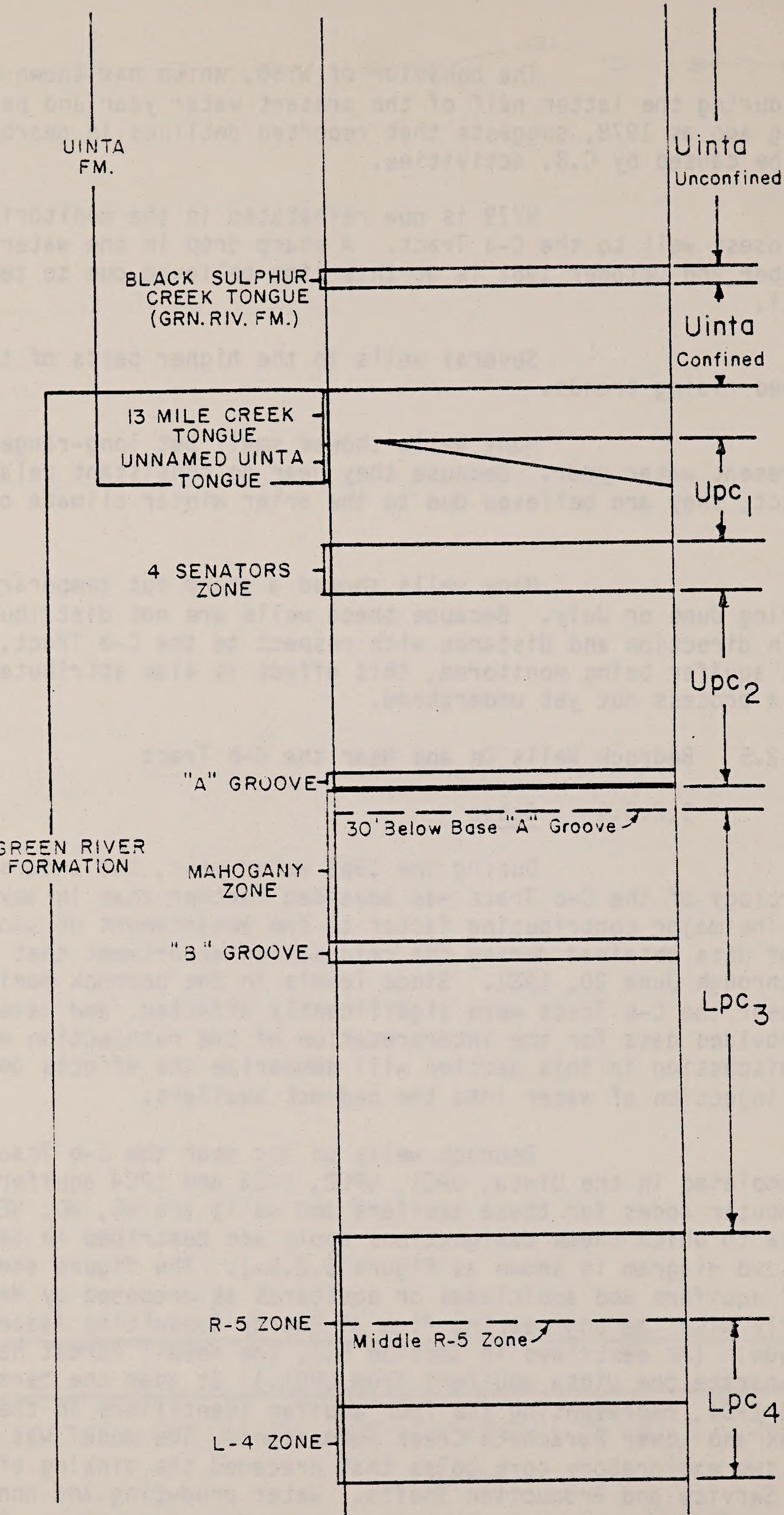


Figure 5.2.5-1

Generalized Stratigraphy C-b Tract

been considered an aquiclude or an aquitard, showed water production in its lower part during the pump spinner tests. Therefore, only the upper 25 feet of the Mahogany Zone was considered in this model as a barrier between UPC2 and LPC3. The lowest of the four aquifer units, LPC4, includes most of the R-5 and L-4 zones of the U.S.G.S. System. In the Newell model, no boundary was designated to separate the Uinta from UPC1.

Water levels have been measured on and off the C-b Tract for many years prior to reinjection. This activity provided a general understanding of the potentiometric water levels within the bedrock. In order to improve this understanding and to relate the observations more closely to the four aquifer model, Mr. David Newell worked out a program to recomplete many of the wells. Recompletions were done before beginning the reinjection test by recementing and reperforating existing strings or by installing, cementing, and perforating new strings. The number of completions per well ranged from one to as many as five including the annular space, and the recompletion program was finished a few months before the start of reinjection. Detailed diagrams of the recompleted wells were provided to the OSO in Development Monitoring Report #6, dated July 15, 1981. The locations of these wells are shown on Figure 5.2.5-2.

Figures 5.2.5-3, -4, and -5 are potentiometric contour maps based on data taken after recompletion but before the reinjection experiment. These contours provide a base for comparison with the reinjection test results. Long term potentiometric configurations prior to reinjection showed an overall slope to the north. Another long term configuration is a trough in the potentiometric surface extending and sloping to the northwest.

Measurements of downhole thermal gradients in thirteen monitoring wells on the C-b Tract was done by Geothermal Surveys, Inc. between October, 1980 and January, 1981. The application of downhole temperature logging was used to obtain data to differentiate hydrologic and stratigraphic units based on the thermal characteristics of the rocks and the possible time related changes in the heat flow.

5.2.5.2. Objectives

The objectives for recompleting and monitoring the wells on and near the C-b Tract are to gather data to use in the determination of the magnitude and the vertical and horizontal extent of effects that dewatering and reinjection activities may have on the ground water.

The recompletion program had as its main objectives, the monitoring of the mining zones and the upper aquifer levels.

The objectives of the downhole thermal logging were to obtain more information about individual aquifer zones and to recognize intervals of lateral flow indicated by changes in the normal thermal gradient. In addition, the purpose was to determine, if possible, aquifer units of relatively high flow and aquitards of relatively little or no flow.

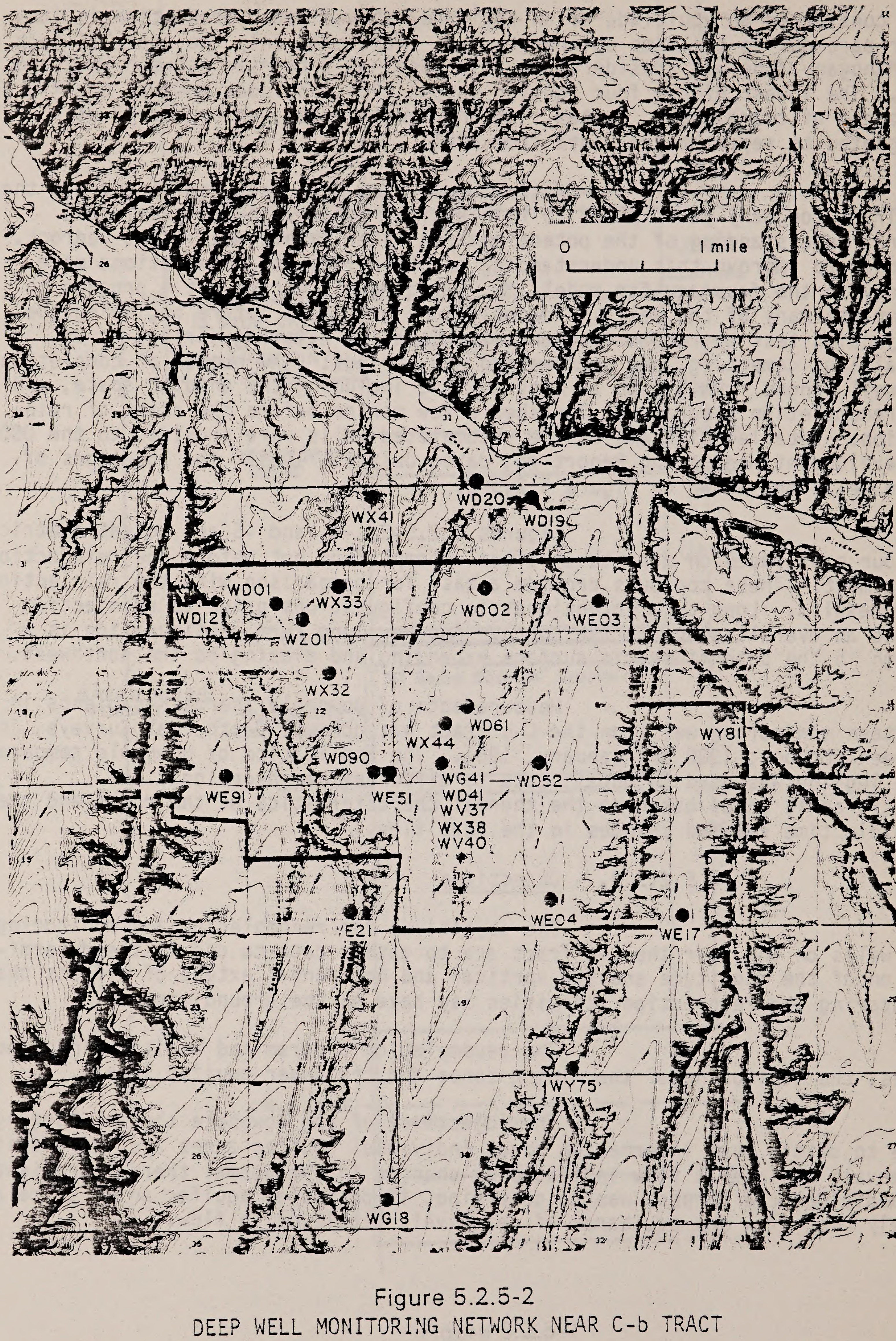


Figure 5.2.5-2
DEEP WELL MONITORING NETWORK NEAR C-b TRACT

FIGURE 5.2.5-3

POTENTIOMETRIC CONTOUR BEFORE REINJECTION - UPC1 WELLS

Units (feet)

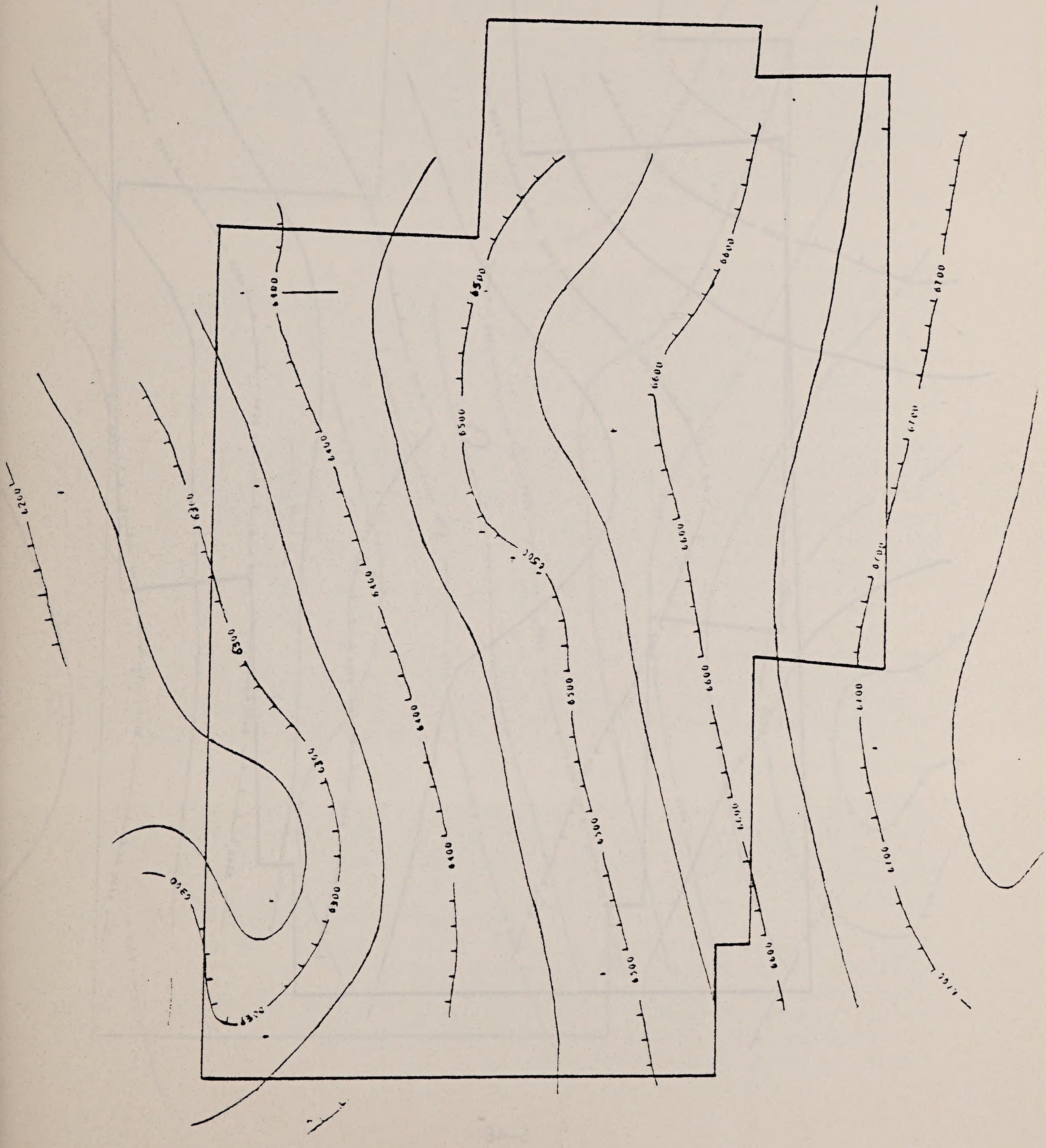


FIGURE 5.2.5-4

POTENTIOMETRIC CONTOUR BEFORE REINJECTION - UPC2 WELLS

Units (feet)

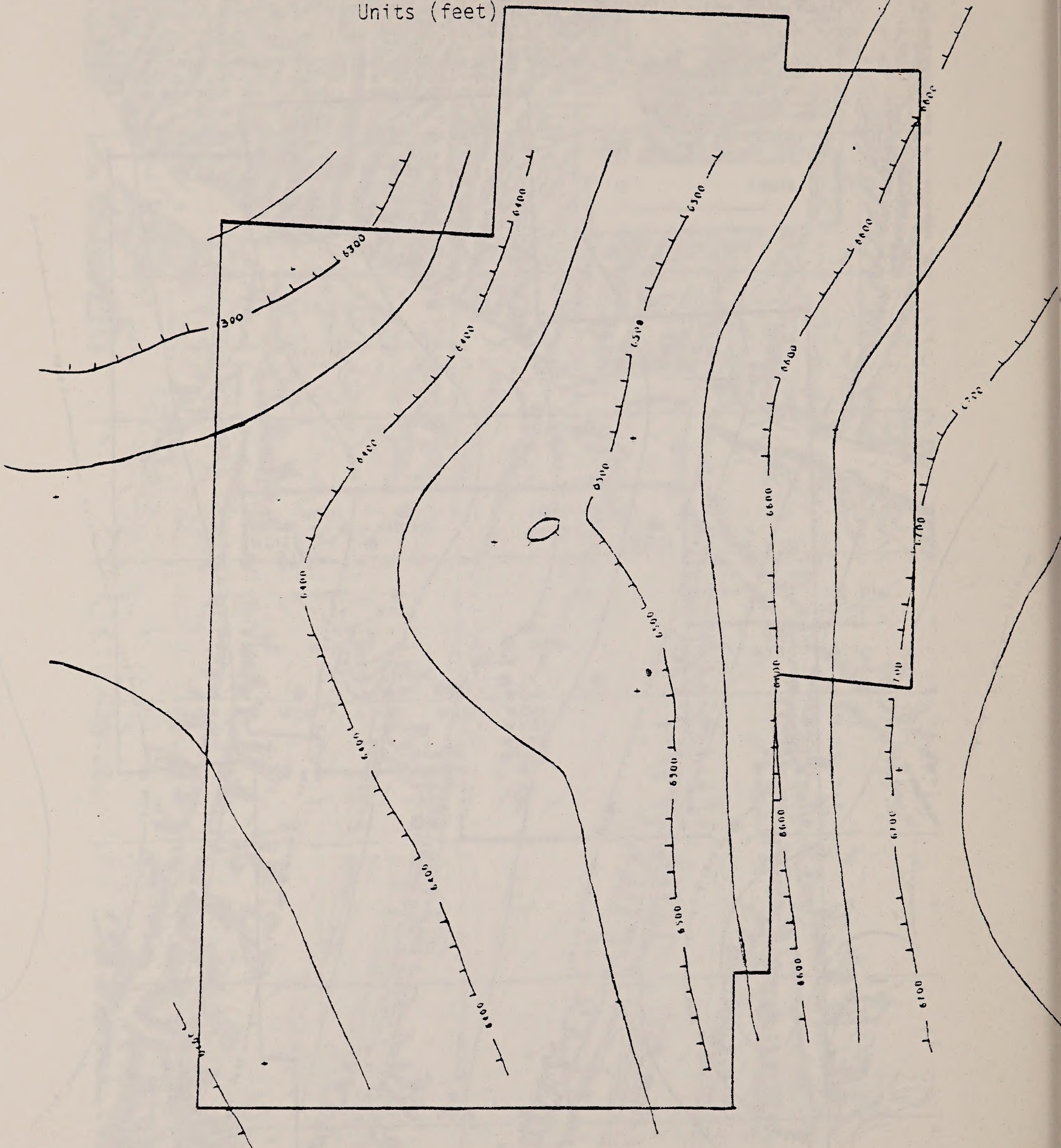
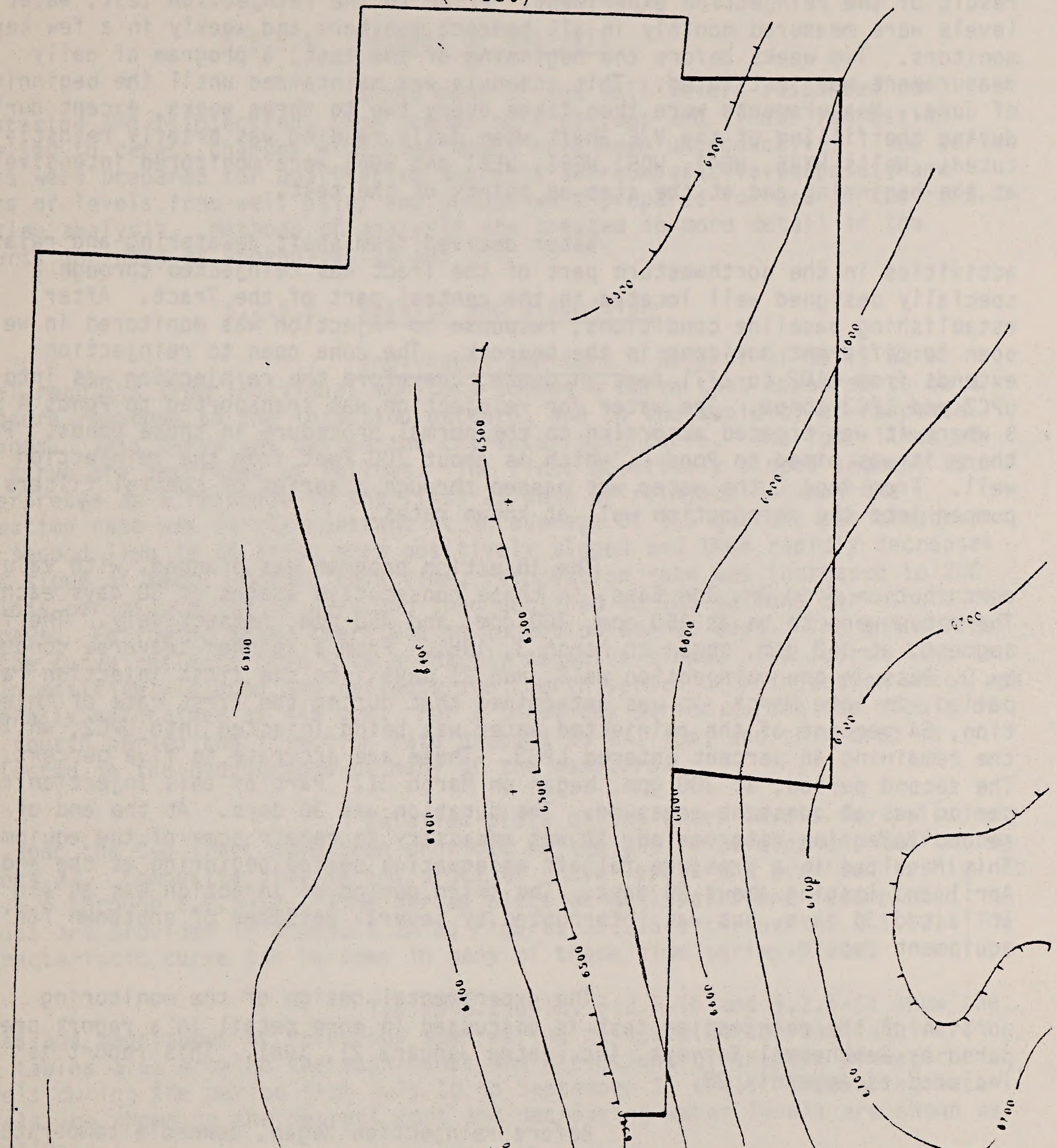


FIGURE 5.2.5-5

POTENTIOMETRIC CONTOUR BEFORE REINJECTION - LPC3 WELLS
Units (feet)



5.2.5.3 Experimental Design

During the 1981 water year, levels in monitoring wells on and near the C-b Tract were measured at different frequencies as a result of the reinjection experiment. Prior to the reinjection test, water levels were measured monthly in all bedrock monitors and weekly in a few key monitors. Two weeks before the beginning of the test, a program of daily measurement was instituted. This schedule was maintained until the beginning of June. Measurements were then taken every two to three weeks, except during during the filling of the V/E Shaft when daily reading was briefly reinstituted. Wells WY45, WG41, WD51,WG51, WE51 and WG61 were monitored intensively at the beginning and at the step-up points of the test.

Water derived from shaft dewatering and related activities in the northwestern part of the Tract was reinjected through a specially designed well located in the central part of the Tract. After establishing baseline conditions, response to injection was monitored in wells open to different horizons in the bedrock. The zone open to reinjection extends from 1102 to 1771 feet in depth, therefore the reinjection was into the UPC2 and LPC3 zones. The water for reinjection was transported to Ponds A and B where it was treated according to the normal procedure in those ponds. From there it was piped to Pond C, which is about 200 feet from the reinjection well. From Pond C the water was passed through a series of control filters and pumped into the reinjection well at known rates.

The injection program was planned, with valuable contribution from Dr. Don Bass, in three consecutive stages of 30 days each. The rates were to be at 150 gpm, 300 gpm, and 450 gpm, respectively. The first segment, at 150 gpm, began on March 3, 1981. From a spinner traverse conducted by D. Bass in the reinjection well, run 21 days into the first injection rate period, in late March, it was determined that during the first rate of injection, 54 percent of the reinjected water was being injected into UPC2, while the remaining 46 percent entered LPC3. These are accurate to five percent. The second period, at 300 gpm, began on March 31. Part of this injection rate period was at constant pressure. The duration was 30 days. At the end of the second injection rate period, it was necessary to repair some of the equipment. This resulted in a pressure falloff observation period beginning at the end of April and lasting about 20 days. The third period of injection was at 450 gpm. It lasted 36 days, but was interrupted by several episodes of shutdown for equipment repair.

The experimental design of the monitoring portion of the reinjection test is discussed in more detail in a report prepared by Geothermal Surveys, Inc. dated January 21, 1981. This report is included as Appendix 2B.

Before reinjection began, downhole temperature logs were made in several of the wells. This was done by lowering a calibrated thermistor probe into each well, stopping at predetermined intervals, allowing the sensor to reach equilibrium, and taking a reading. Temperatures in many of the wells were logged again after reinjection. Pre- and post-injection changes were recorded within the target aquifer zones, but not in most of the formations above the injection zones.

More details on the experimental design of down-hole temperature logging on the C-b Tract are provided in a report prepared by Geothermal Surveys, Inc. dated February 19, 1982. This report is included as Appendix 2C.

5.2.5.4 Methods of Analysis

Since many of the well levels responded to dewatering and reinjection, time trends were obvious and linear regression modeling to detect changes with time would have been unproductive. Time series plots were prepared for qualitative analysis and comparative purposes, and plots of levels from well pairs and groups were prepared for use in the reinjection analysis. Methods of analysis are treated in more detail in the reports included as Appendices 2B and 2C.

5.2.5.5 Results and Discussion

Individual monitors - Records of daily water level readings from individual monitors showed a curve that appeared to be a pressure response to the injection pattern, due to the rapidity of response changes. This curve was called the characteristic curve. The four limbs of the curve are described as follows: The first positively sloped segment is interpreted as a response to the first 23 days of reinjection when the injection rate was fairly constant at an average of 155 gallons per minute. The second limb is at first more positively sloped and then rapidly decreases to a slope of zero. During this time, reinjection rate was increased to 300 gallons per minute for 15 days and then declined to 135 gallons per minute for 12 days. Following this, there was no injection for 20 days. The third limb of the curve reflects this with a sharply negative slope. The fourth limb is again positively sloped and reflects the fourth period of reinjection which was generally maintained at 445 gpm. For a three day period during the middle of the fourth period the injection rate dropped to 171 gpm, and this drop is reflected in the hydrographs of many of the monitors.

Detailed plots of the water levels for wells on and near the C-b Tract have been provided to the OSO in Development Monitoring Report #7. Composite time series plots of these levels are provided as Figures 5.2.5-6 through 5.2.5-12. Time series plots of well pairs and recompleted groups are provided in Appendix 2A as Figures A5.2.5-1 through A5.2.5.19. The characteristic curve can be seen in many of these time series plots.

Tables 5.2.5-1a, 5.2.5-1b and 5.2.5-1c show the types and magnitudes of responses seen during reinjection for each aquifer. The tables also provide the magnitudes and directions of changes of water levels during the period from July 10 to September 7, 1981. Increasing water levels are shown to the nearest foot and decreasing water levels are shown as negative.

The pressure response was seen in most of the wells on and near the C-b Tract. The magnitude of response was greatest in LPC3, moderate in UPC2, and least in UPC1/Uinta. Based on the character of the response, we believe that the Aquifer Test Pad is largely responsible.

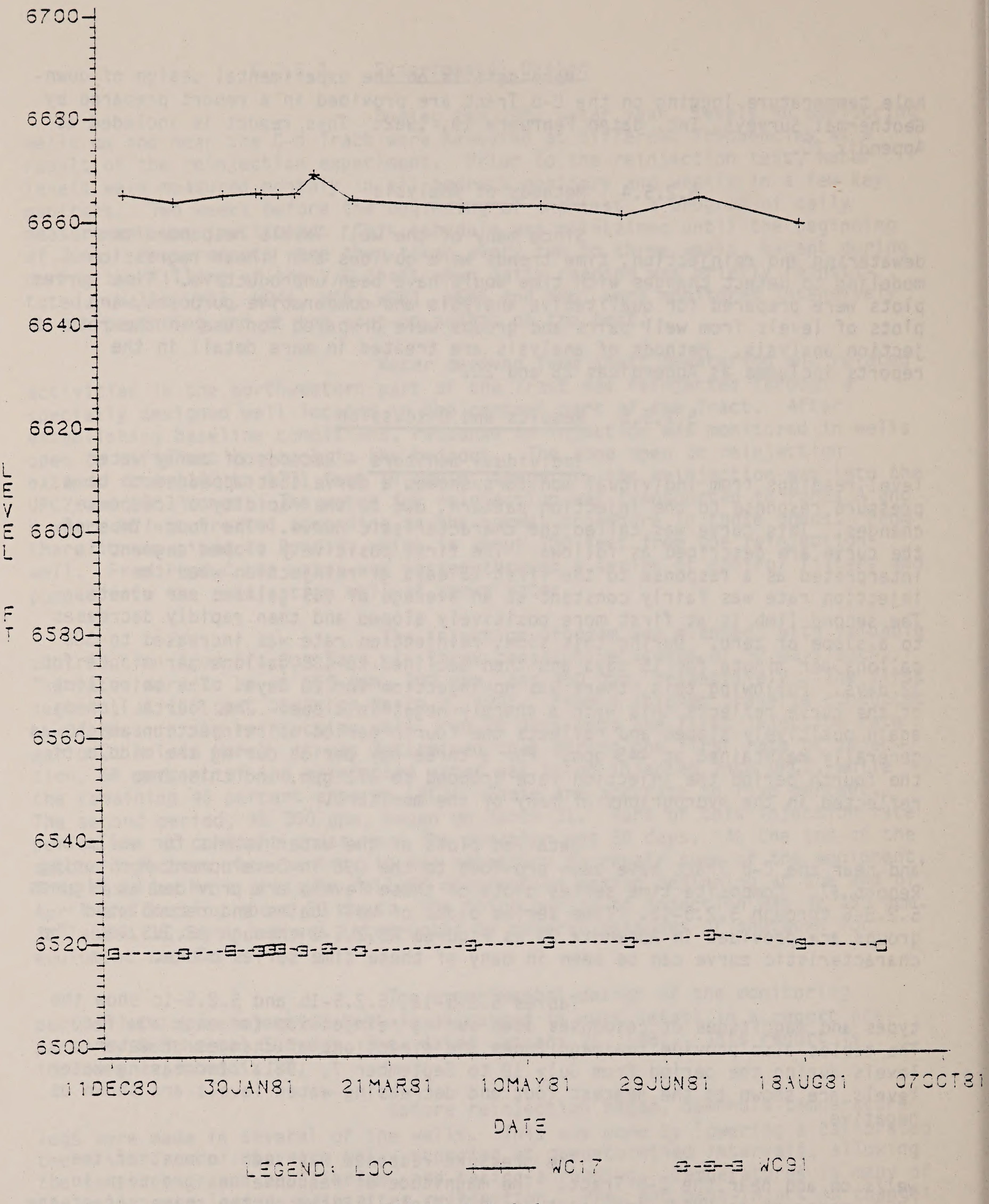


FIGURE 5.2.5-6

COMPOSITE PLOT OF LEVELS IN UINTA WELLS ON AND NEAR THE C-b TRACT

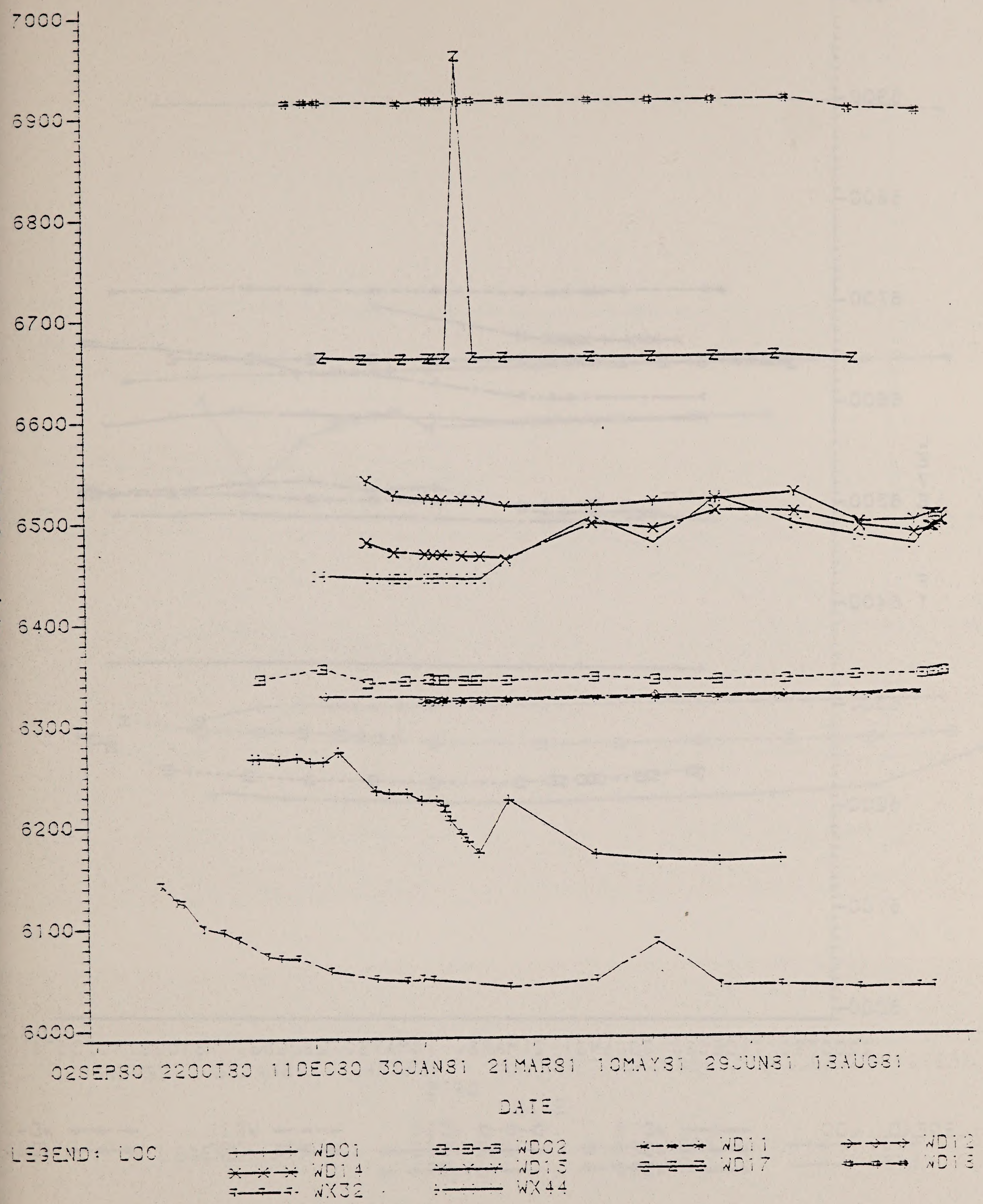


FIGURE 5.2.5-7 UPPER AQUIFER & UPC1 WELL LEVELS

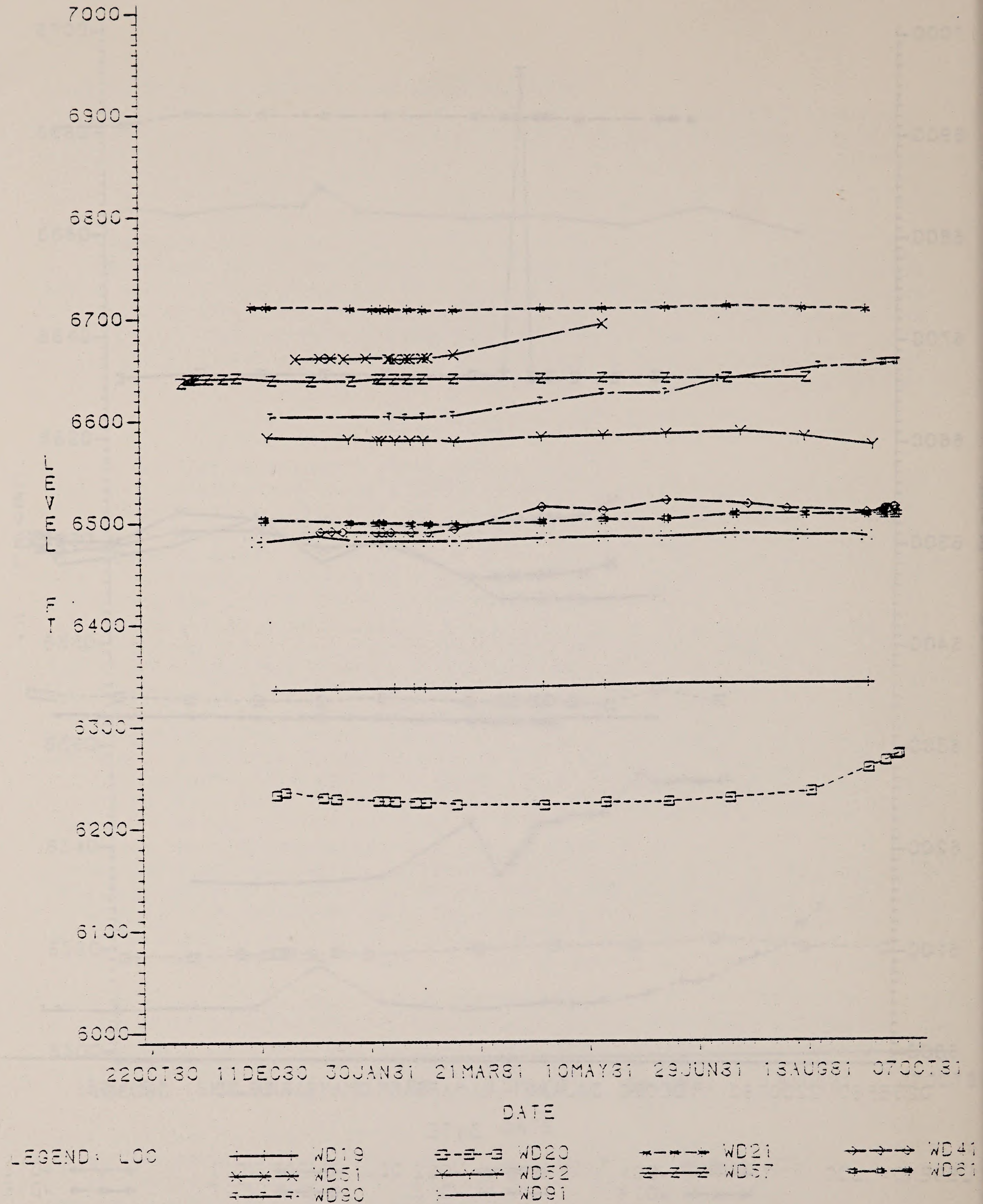


FIGURE 5.2.6-8 UPC1 WELL LEVELS

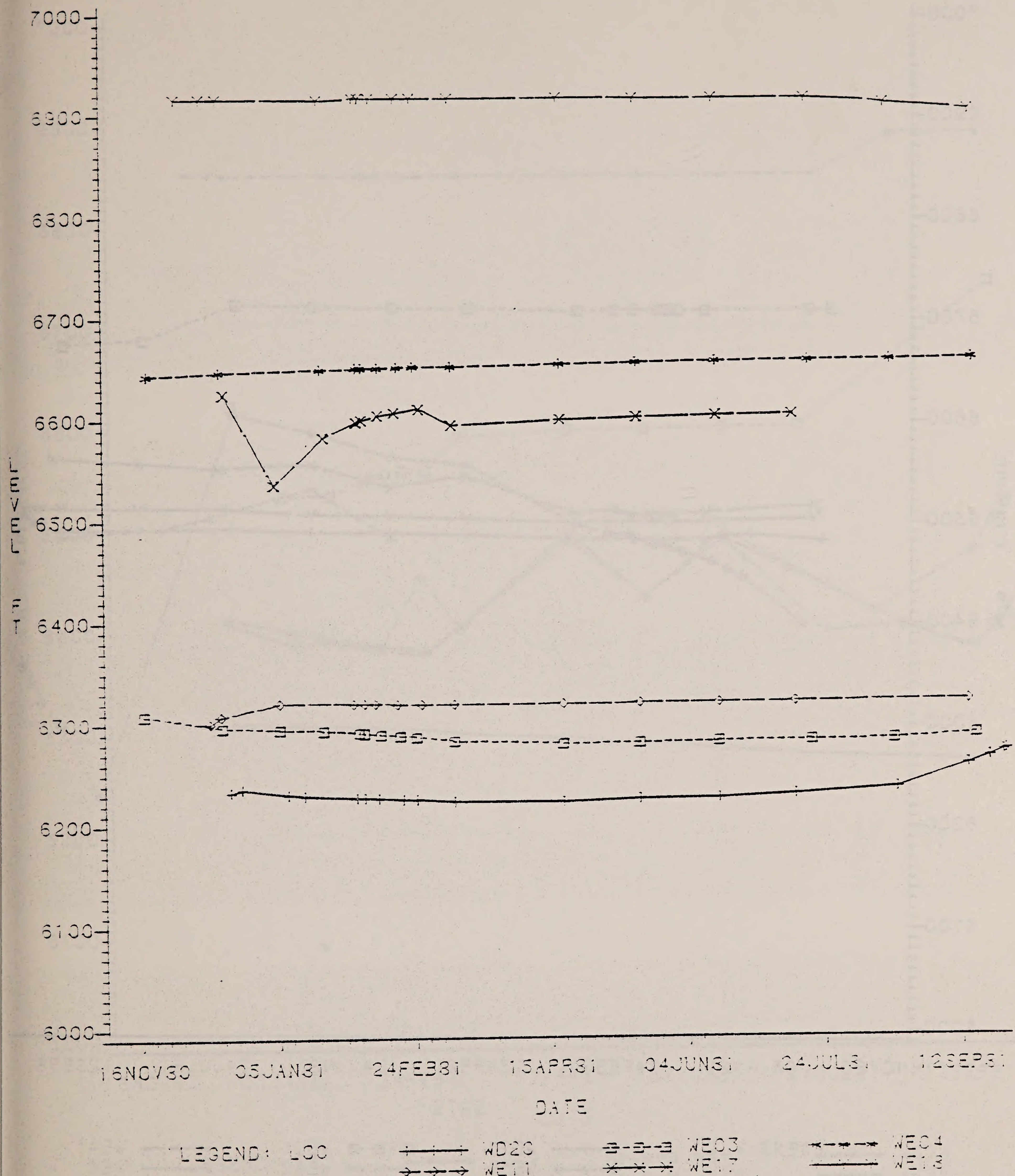


FIGURE 5.2.5-9 UPC1 & UPC2 WELL LEVELS

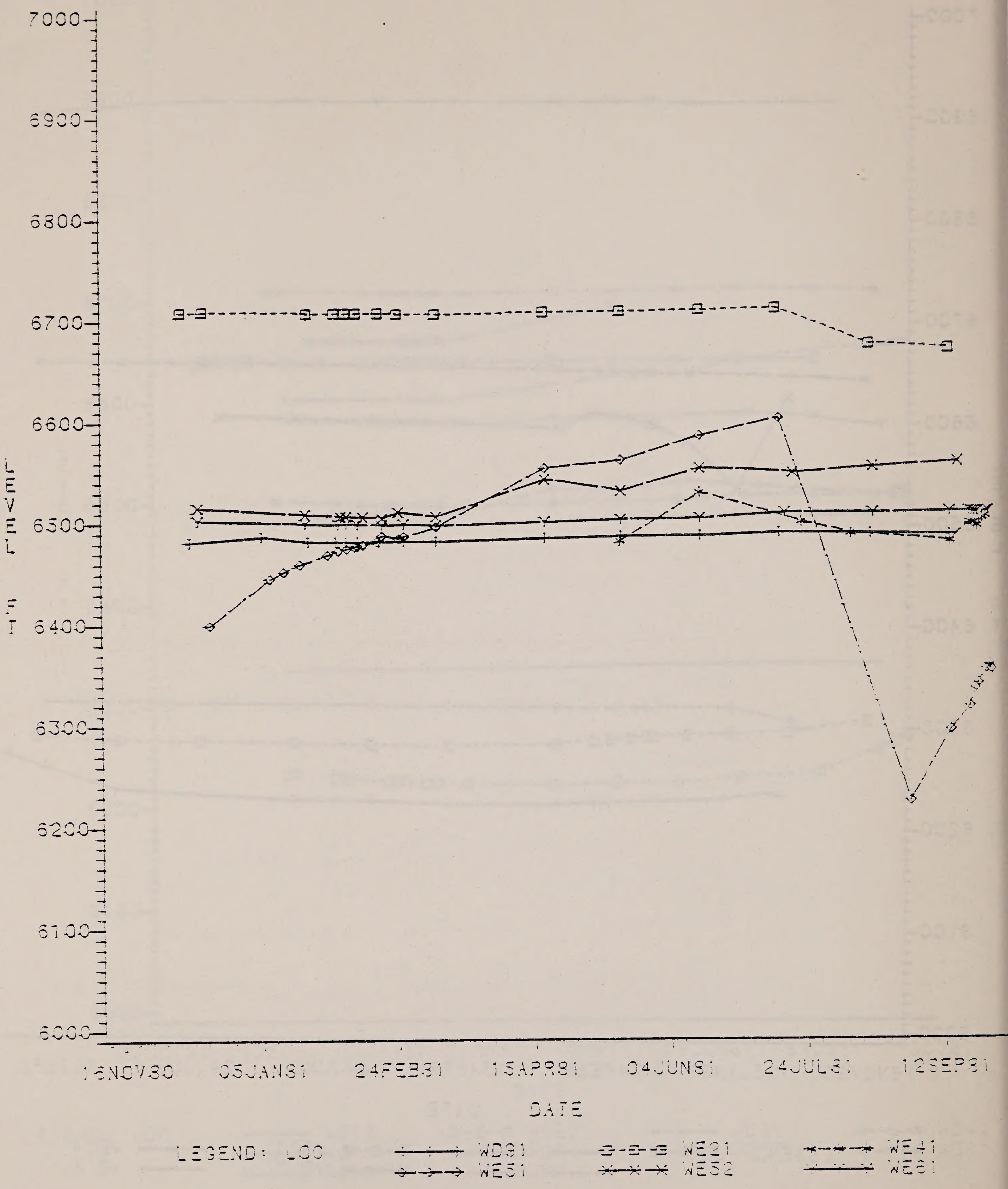


FIGURE 5.2.5-10 UPC2 WELL LEVELS

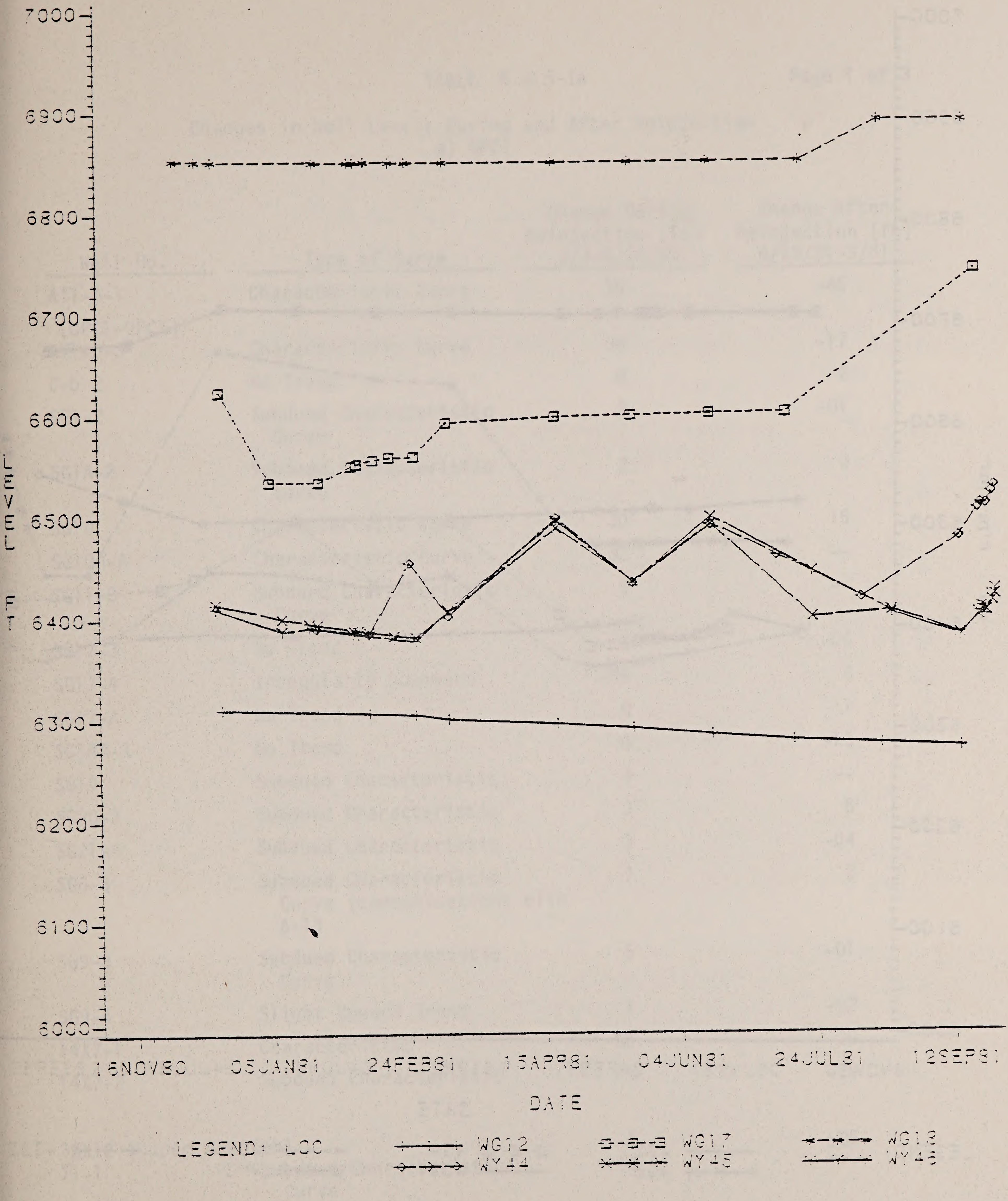


FIGURE 5.2.5-11 LOWER AQUIFER & LPC3 WELL LEVELS

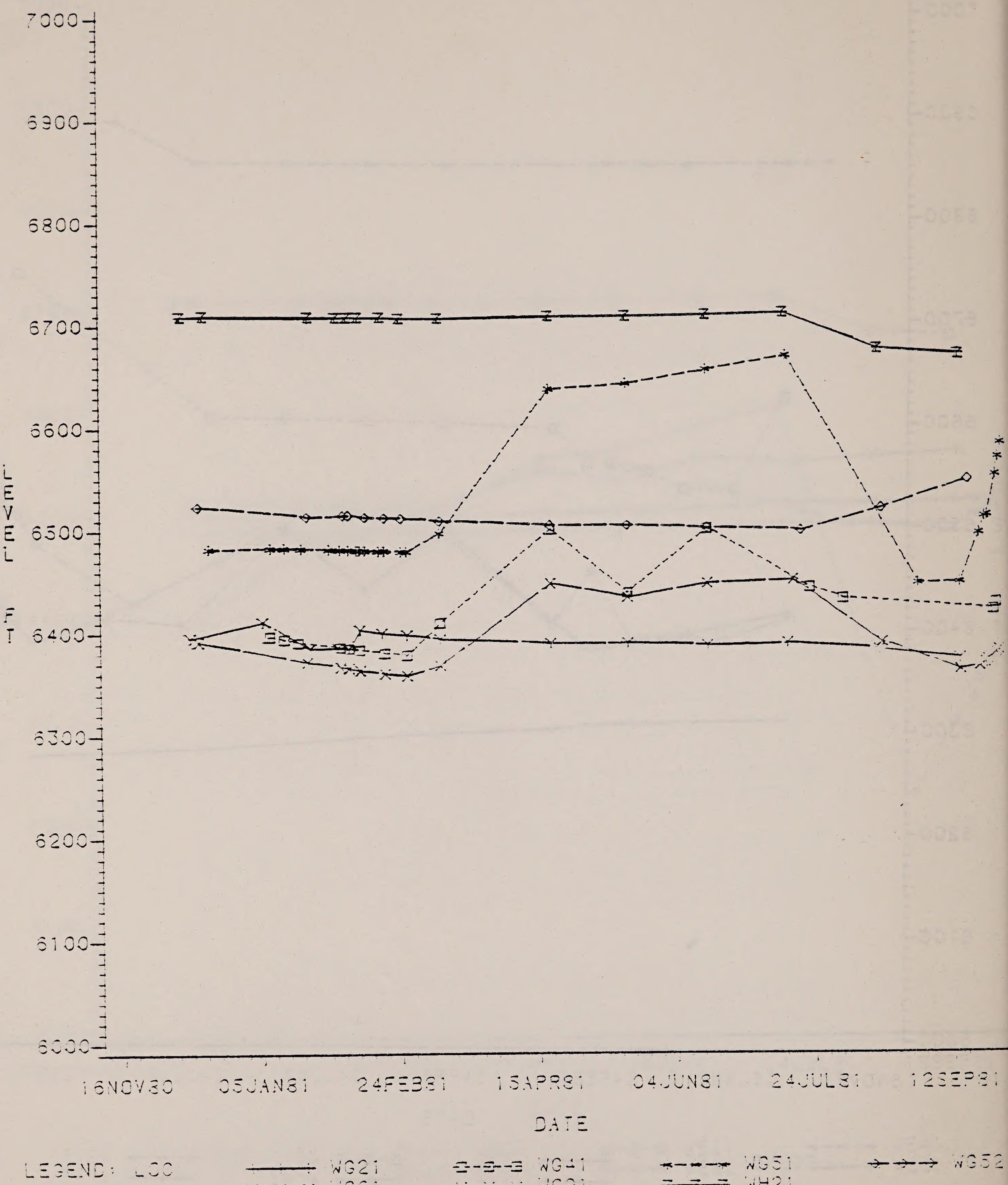


FIGURE 5.2.5-12 LPC3 & LPC4 WELL LEVELS

TABLE 5.2.5-1a

Changes in Well Levels During and After Reinjection
a) UPC1

Well No.	Type of Curve	Change During Reinjection (ft) 3/3-6/30/81	Change After Reinjection (ft) 6/30/81-9/81
AT1-A-1 (UPC1-UPC2)	Characteristic Curve	79	-45
AT1-D-3	Characteristic Curve	36	-17
C-b 2	No Trend	0	2
SG1-2	Subdued Characteristic Curve	2	-01
SG1A-2	Subdued Characteristic Curve	2	0
SG10	Characteristic Curve	30	15
SG10A-A	Characteristic Curve	32	--
SG11-3	Subdued Characteristic Curve	9	--
SG17-3	No Trend	0	-04
SG17-4	Irregularly Downward	-06	2
SG17-A	No Trend	0	1
SG18A-3	No Trend	0	-13
SG19	Subdued Characteristic	4	--
SG20-3	Subdued Characteristic	3	8
SG21-4	Subdued Characteristic	3	-04
SG6-3	Subdued Characteristic Curve (communications with 6-1)	7	2
SG9-3	Subdued Characteristic Curve	5	-01
SG9-4	Slight Upward Trend	1	-02
14X7-1	Characteristic	66	-39
14X7-2	Subdued Characteristic	8	-25
32X12 (Upper Aquifer)		1	-05
71-1	Subdued Characteristic Curve	10	--
41X13	Generally Smoothly Upward	37	12

TABLE 5.2.5-1b

b) UPC1

Well No.	Type of Curve	Change During Reinjection (ft) 3/3-6/30/81	Change After Reinjection (ft) 6/30/81-9/81
AT-1A	Characteristic Curve	81	-110
ATIC-3	Characteristic Curve	79	-46
AT10-2	Characteristic Curve	45	-45
C-b 1	Irregular	-05	--
C-b 3	Generally Smoothly Downward	-03	2
C-b 4	Generally Smoothly Upward	4	1
SG1A-1	Generally Smoothly Upward	1	-03
SG10A-2	Characteristic Curve	110	-359
SG11-2	Characteristic Curve	63	-07
SG17-2	Smoothly Upward (Communicates with 17-1)	11	--
SG18A-2	No Trend (Communicates with 18-3)	-01	-13
SG20-2	Irregularly Downward	-54	-72
SG21-3	Subdued Characteristic Curve (Communicates with 21-2, 4)	3	-40
SG6-1	Subdued Characteristic Curve (Communicates with 6-3)	7	2
SG9-2	Subdued Characteristic Curve	23	-11

TABLE 5.2.5-1c

c) LPC3

Well No.	Type of Curve	Change During Reinjection (ft) 3/3-6/30/81	Change After Reinjection (ft) 6/30/81-9/81
AT-1	Characteristic Curve	121	-10
AT1C-1	Characteristic Curve	124	-116
AT1C-2	Characteristic Curve	132	-129
SG1-1	Generally Downward	-23	-08
SG10A-1	Characteristic Curve	167	-195
SG11-1	Generally Downward	-11	62
SG17-1	Smoothly Upward (Communicates with 17-2)	11	--
SG18A-1	No Trend	0	39
SG21-2	Subdued Characteristic Curve (Communicates with 21-3, 4)	3	-41
SG6-2	Characteristic Curve	113	-98
SG9-1	Smoothly Downward	-08	-14

Several wells did not show response to the reinjection. The failure to respond in many cases can be attributed to distance between the injection well and the monitor. In other cases, where water levels decreased during reinjection, decreases may be due to their proximity to the shafts where water was being withdrawn at an average rate of about 1400 gpm during the reinjection period.

Two pairs, which monitor UPC2 and LPC3, showed response to reinjection in the UPC2 monitor and failure to respond in the UPC3 monitor. These pairs are WE52/WG52 and WE91/WG91. Possible explanations are relief of pressure in LPC3 due to upward or downward flow, or barriers in LPC3 to transmission of the pressure wave. WG52 in LPC3 has shown a significant increase in water level since the completion of the reinjection monitoring program. WG91 in LPC3 has continued to show a decline. Graphs of levels with respect to time for these well pairs are provided in Appendix 2A.

Elevations of the Potentiometric Surfaces - Figures 5.2.5-3, -4, and -5 show the contoured elevations of the potentiometric surfaces for UPC1/Uinta, UPC2, and UPC3 in Feburary 1981, before reinjection began. They show the northerly slope of the potentiometric surface. Differences in configuration may be due to differences in the distribution of the monitoring wells. Only the UPC1 Uinta plots shows a depression near the shafts, provided by data from WD01. In general, the pre reinjection data away from the near vicinity of the shafts show a range of about 300 feet in the potentiometric surface elevation. The highest elevations were at the southern boundary of the Tract. Here, the UPC1 Uinta surface was the highest and LPC3 was the lowest. The UPC1 Uinta head was as much as 100 feet higher than LPC3. Similar relationships occurred through the central part of the Tract.

Figures 5.2.5-13, -14, and -15 show the elevations of the potentiometric surface on April 19, 1981, after a month and a half of reinjection and well into Step 2. For UPC1 Uinta, a little change had occurred since the February readings in head elevation, generally slight, throughout the Tract. For UPC2 and LPC3, however, the differences were marked. In the central part of the Tract, some of the head relationships were now reversed. UPC2 heads were at higher elevation than UPC1 Uinta, and some of the LPC3 heads were above those of both UPC2 and UPC1 Uinta. This was especially true in the area of the aquifer test pad and the reinjection site.

It is significant that, except for the aquifer test pad, so little change occurred in the UPC1 Uinta potentiometric surface when significant changes occurred in UPC2 and LPC3. This suggests that there is little hydrologic continuity between the shallower and the deep formations.

The largest head increases in each of the hydrologic units were 110 feet in UPC2 and 167 feet in LPC3. The change of 79 feet at the aquifer test pad is believed due to communication between aquifer units through open holes.

The lateral extents of the affected zones were on the order of one to two miles centered around the injection site, and remained mostly within the Tract.

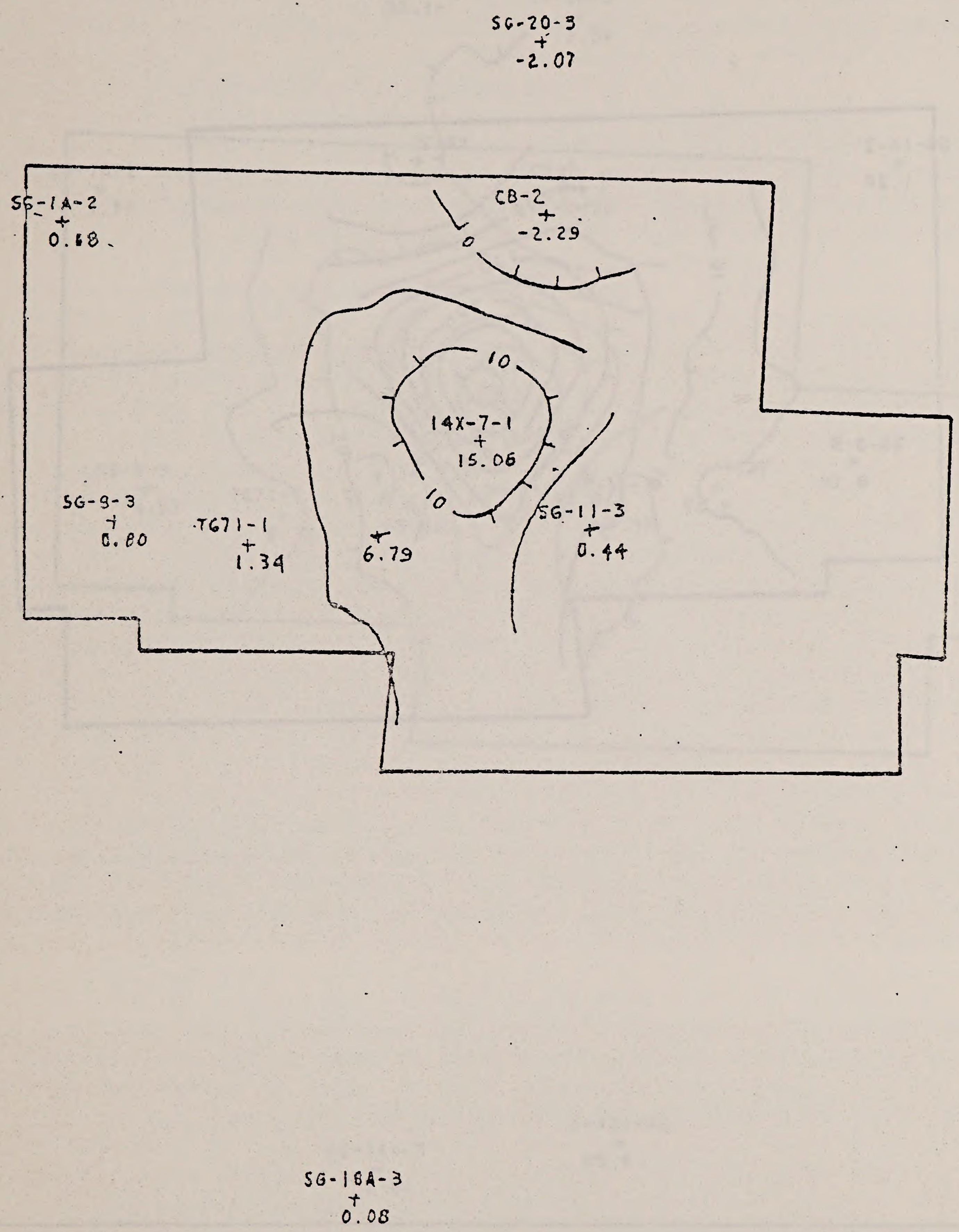


FIGURE 5.2.5-13

REINJECTION POTENTIOMETRIC SURFACE DIFFERENCE MAP FOR MARCH 30 - MARCH 3

UPC1, B WELLS

Contour Intervals = 5.0'

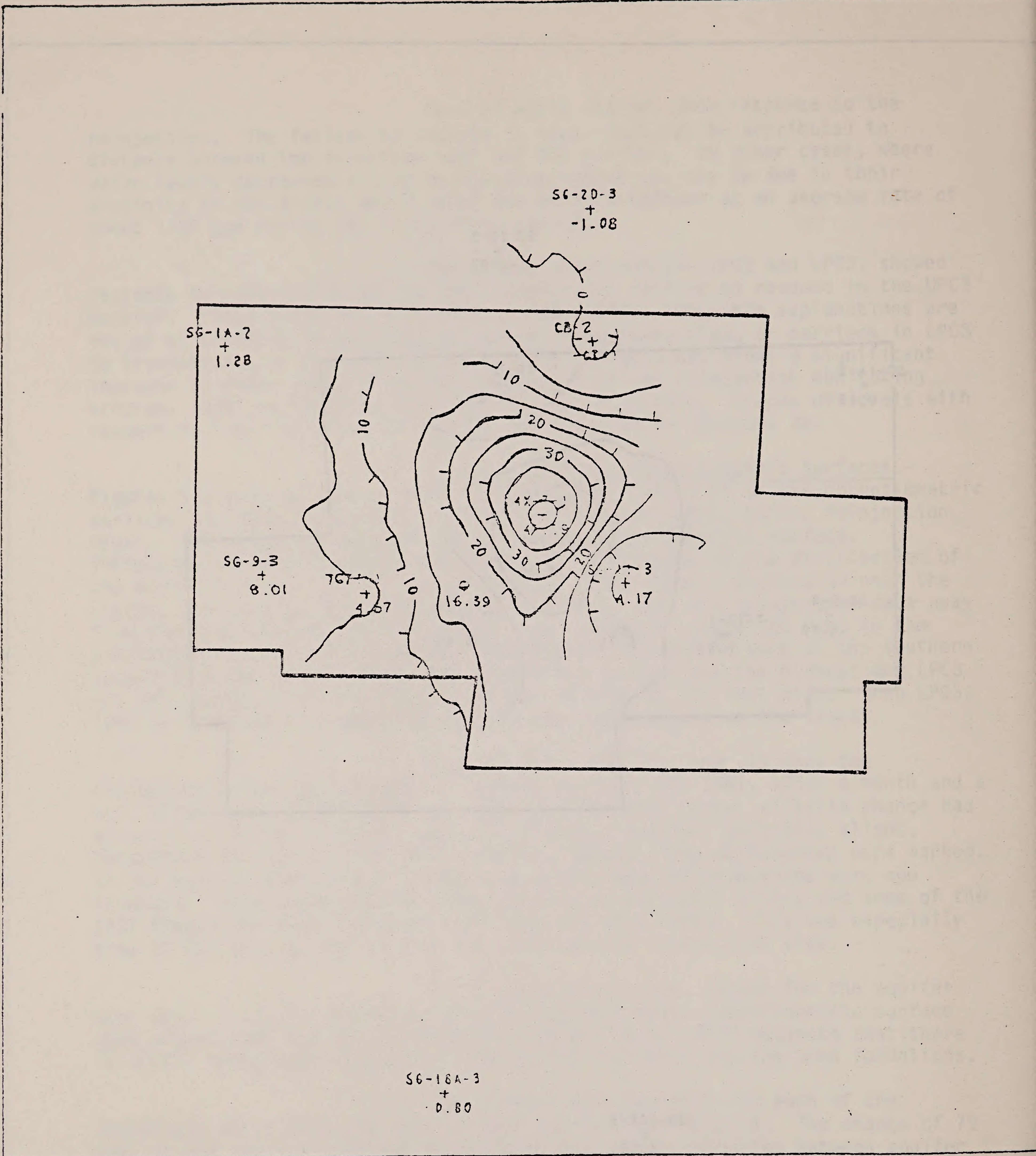


FIGURE 5.2.5-14

REINJECTION POTENTIOMETRIC SURFACE DIFFERENCE MAP FOR APRIL 29 - MARCH 3
UPC1, B WELLS

Contour Intervals = 5.0'

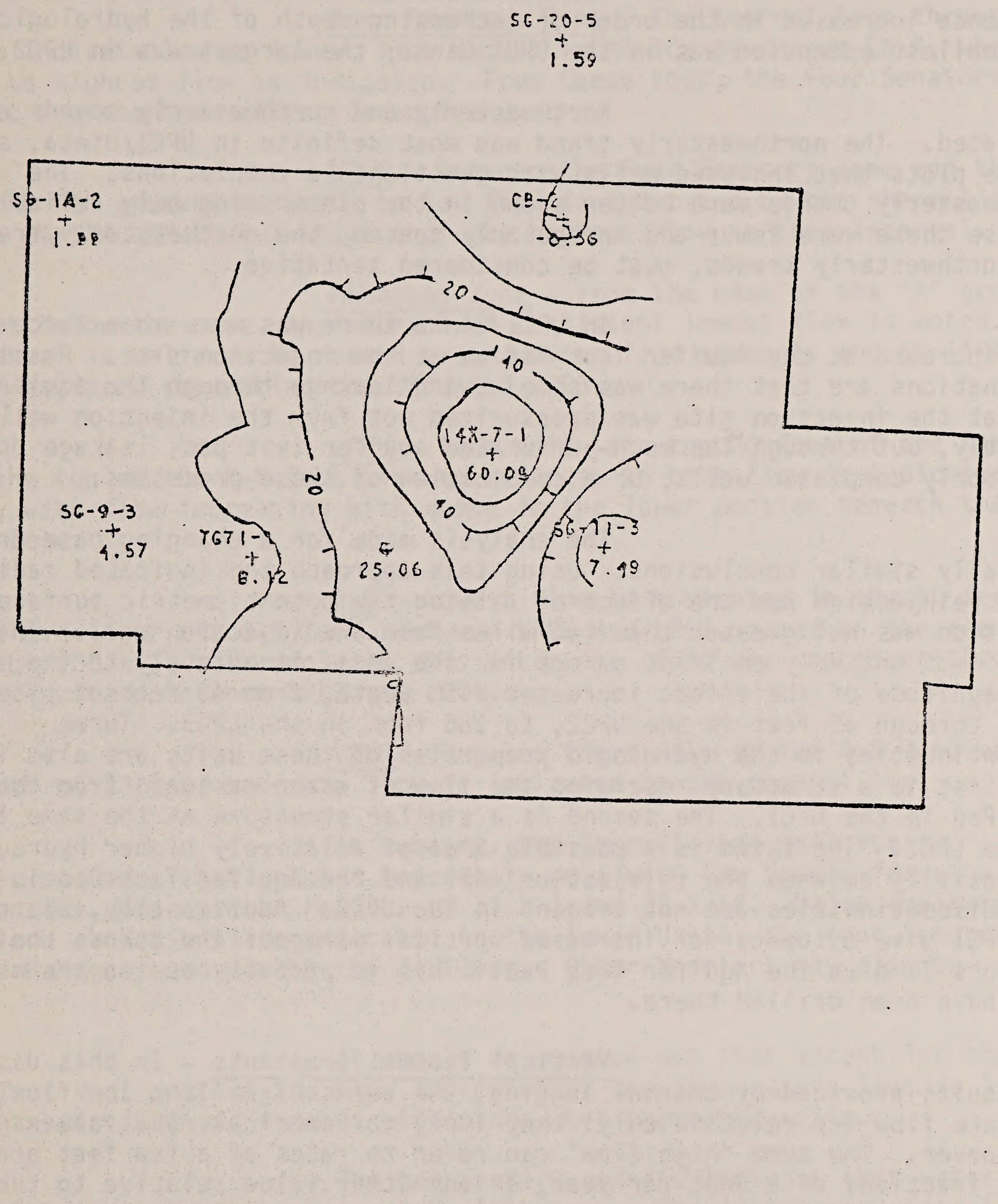


FIGURE 5.2.5-15

REINJECTION POTENTIOMETRIC SURFACE DIFFERENCE MAP FOR JUNE 24 - MARCH 3
UPC1, B WELLS

Contour Intervals = 10.0'.

Most of the off-Tract extension was to the south, perhaps as much as a mile. Off-Tract extension to this distance is not reliable, as this is based partly on wells with questionable completions.

The indicated amount of spread of the zone of influence increased in the order of increasing depth of the hydrologic units. The smallest extension was in the UPC1 Uinta; the largest was in LPC3.

Northwesterly and northeasterly trends were indicated. The northwesterly trend was most definite in UPC1/Uinta, shown best in the plots that included wells with questionable completions. The northeasterly trends were better shown in the plots using only reliable wells. Because these were fewer and irregularly spaced, the northeasterly trends, like the northwesterly trends, must be considered tentative.

In UPC1/Uinta there was more than twice as much head increase at the Aquifer Test Pad as at the injection site. Possible explanations are that there was some upward leakage through the aquitards; UPC1 at the injection site was pressurized not from the injection well directly, but through the much-perforated aquifer test pad; leakage occurred via poorly completed wells; or a combination of these processes.

The analysis made for a changing base provided generally similar conclusions. Using this approach the indicated radius over which reinjection had the effect of raising the potentiometric surface elevation was not greater than two miles from the injection well. This places the effect entirely on Tract except for the areas immediately to the south. The magnitude of the effect increased with depth, from 43 feet of rise in the UPC1, through 65 feet in the UPC2, to 166 feet in the LPC3. Three discontinuities in the hydrologic properties of these units are also indicated. The first is a structure retarding the flow of water eastward from the Aquifer Test Pad in the UPC1. The second is a similar structure at the same location in the LPC3. The third is a possible area of relatively higher hydraulic conductivity between the reinjection well and the Aquifer Test Pad in the LPC3. Such discontinuities are not evident in the UPC2. Additionally, the data for the UPC1 give evidence for increased vertical permeability across the Four Senators Zone at the Aquifer Test Pad. This is probably due to the many wells that have been drilled there.

Vertical Thermal Gradients - In this discussion of results provided by thermal logging, the terms high flow, low flow, and moderate flow are relative only; they imply no numerical rate values whatsoever. The term "high flow" can refer to rates of a few feet per year, small fractions of a foot per year, or any other value relative to the other terms.

There is considerable range in groundwater activity from well to well within the same hydrologic unit, as indicated by the downhole thermal logs. The flow is controlled by fractures and by general lithology, which in turn influences the fracture patterns.

UPC1/Uinta - Most of the Uinta Formation (UPC1) shows moderate to high flow (in relative terms only). The lower 100 ft of the Uinta indicates low to lowest flows in most wells, which is interpreted as

retarding ground water flow somewhat in most areas. This interval may represent a barrier which separates the Uinta hydrologically from the UPC1. In the upper Parachute Creek Member above the Four Senators Zone, the thermal logs indicate that flow varies widely from highest to lowest.

Four Senators Zone - The thermal logs throughout this zone indicate low to lowest flow except in AT-1C, AT-1A and Cb-4, where moderate to highest flow is indicated. From these logs, the Four Senators Zone appears to represent an effective aquitard.

UPC2 - Between the Four Senators Zone and the base of the "A" groove, moderate to low flow is indicated by the thermal logs, except in SG-18A and 33-X-1 which indicate highest flow in this interval.

Mahogany Zone - From the base of the "A" groove to 30 feet below the base, an interval of consistent lowest flow is noted. This interval is believed to retard ground water flow strongly and is likely the major aquitard separating the UPC2 and LPC3.

LPC3 - From below the top 30 feet of the Mahogany Zone to the top of the R-5 Zone, low to moderate to high flow is indicated by the logs, with flow increasing with depth in the lower portion beneath the Mahogany Zone.

R-5 - Lowest flow is indicated in the 50 feet above the middle of the R-5 Zone, between LPC3 and LPC4, based on the one thermal log (33-X-1) that included this interval. This may represent the effective aquitard between LPC3 and LPC4.

LPC4 - Between the middle of the R-5 Zone and the total depth of 33-X-1, moderate flow is indicated by the thermal log.

In summary, the thermal logs indicate a hydrologic sequence that relates moderately well with the Newell format based in turn on the pump spinner results of 33-X-1 and 32-X-12. Major aquitard and or aquiclude conditions are indicated in the lower Uinta, the Four Senators, the Upper Mahogany and within the R-5 Zone. Other barriers may also be present.

It should be pointed out that except for the Aquifer Test Pad, most of the flow indicated by the temperature logs is lateral rather than vertical and remains within the more permeable units.

The temperature results indicate that water flow is controlled both by fractures and by lithology. The lithologic control is not, except for the leached vuggy zones, due primarily to porous medium conditions. It is because rocks of different lithologic character cause differences in the frequency, orientations, and openness of fractures. Thus, there is a crude stratigraphic arrangement of the distribution of fractures.

Exceptions to the general statements discussed in the preceding paragraphs are the wells in the Aquifer Test Pad. Here, moderate to high flow is indicated throughout most intervals. This is believed due to

the presence of open holes in the Aquifer Test Pad that cause greater than normal vertical flow.

Further details, conclusions and interpretations are provided in the reports included as Appendices 2B and 2C with respect to the reinjection test, downhole thermal logging, and interpretation of these results.

Some questions, concepts, and working hypotheses with respect to Piceance Basin hydrology have been assembled by Joseph H. Birman of Geothermal Surveys, Inc. This document has been included as Appendix 2D. The paper does not include new interpretations of the hydrologic system, but is an extrapolation of some established concepts and modification of others using existing data. The report suggests that lateral groundwater migration within much of the Green River formation may be so slow as to be nonmoving; that away from faults the deep ground water may not be in significant communication with the near surface water; that some of the water in the Green River formation may be ancient and is not being actively recharged now; and that some of the leaching of the Green River formation may have occurred in ancient times, after which continuity of open space was destroyed.

In supporting these geohydrologic investigations Cathedral Bluffs Shale Oil Company has provided data that we believe will make a unique contribution to the understanding of Piceance Basin hydrology. The discussion and tentative conclusions provided here should be considered only a first step in the interpretations and analyses that may ultimately be made.

5.2.6 Water Management

5.2.6.1 Scope

Water produced in the C-b Tract in excess of daily requirements is managed by temporary impoundment, reinjection, land application through sprinkling, discharge, or any combination of these techniques. The 1980 Annual Report described the details of the water management system on the C-b Tract. No changes to this system were made during 1981.

Water from the ponds was either applied through the sprinkler system or discharged depending on the quantity, quality, or time of year. Discharge flow was monitored at Station WU42 in Little Gardenhire Gulch and at Station WU45 downstream from the confluence of Little Gardenhire Gulch and Piceance Creek. Reinjection was discussed in 5.2.5 and in Appendix 2B. Dewatering in the V/E Shaft was discontinued in September 1981 and the V/E Shaft was allowed to flood. After September, reinjection served as the primary mode of disposal for produced water.

Water was produced from groundwater through the dewatering process. Although water flow into shafts and related works was minimized as much as possible by grouting and concrete shaft liners, it was necessary to dewater shaft works by pumping to the surface in a series of lifts. This surplus water was eliminated through the water management system.

5.2.6.2 Objectives

The objective in water management is to dispose of excess water generated from various activities, principally the water pumped from the shafts and related workings. Treatment of water quality for the present water management system is discussed in Section 5.3. The quantity of water routed into the temporary storage facilities and the quantity removed from storage by discharge or other means must comply with requirements of the Tract NPDES Permit, the State Subsurface Disposal Permit for reinjection of mine water, and the Water Augmentation Plan.

5.2.6.3 Experimental Design

Waters pumped into the ponds and discharged from Pond B into Little Gardenhire Gulch are measured. The NPDES Permit limits discharge volume with specific permit criteria based on water quality impacts to Piceance Creek. The design is to compare discharge volumes from Pond B to that of total streamflow in Piceance Creek downstream of the discharge point. Seepage monitoring well WW22 and WW13 are designed to monitor seepage from the holding ponds.

5.2.6.4 Discussion and Results

Figure 5.2.6-1 is a graph of the water levels in the Seepage Monitoring Wells WW13 and WW22 during the 1981 water year.

Table 5.2.6-1 is a summary of water management activities on the C-b Tract during the 1981 water year. The total water pumped and its disposition is shown on this table. The cessation of pumping water from the V/E Shaft is readily apparent in the amounts shown for total water pumped and total water treated.

Table 5.2.6-2 lists the monthly totals for NPDES releases from the WN40 A/B discharge, and shows the daily total where discharge was intermittent. Table 5.2.6-3 compares discharges measured at WN40 with streamflow measured at WU61.

No changes in flow patterns in the springs, seeps, or surface flows can be attributed to the reinjection activities. Variations in these processes have been occurring long before the reinjection test and are primarily related to climate and agricultural diversions. The alluvial wells showed no overall noticeable effects from the reinjection test.

5.2.7 Data Comparisons Identified by the Water Augmentation Plan

5.2.7.1 Scope

Specific comparisons of data were identified by the Water Augmentation Plan (WAP). The WAP identified a comparison between flow in Piceance Creek with precipitation measured at various flow and precipitation measurement stations in the Tract area and at the Little Hills Station. The wintertime flow on Piceance Creek at WU00 and the precipitation

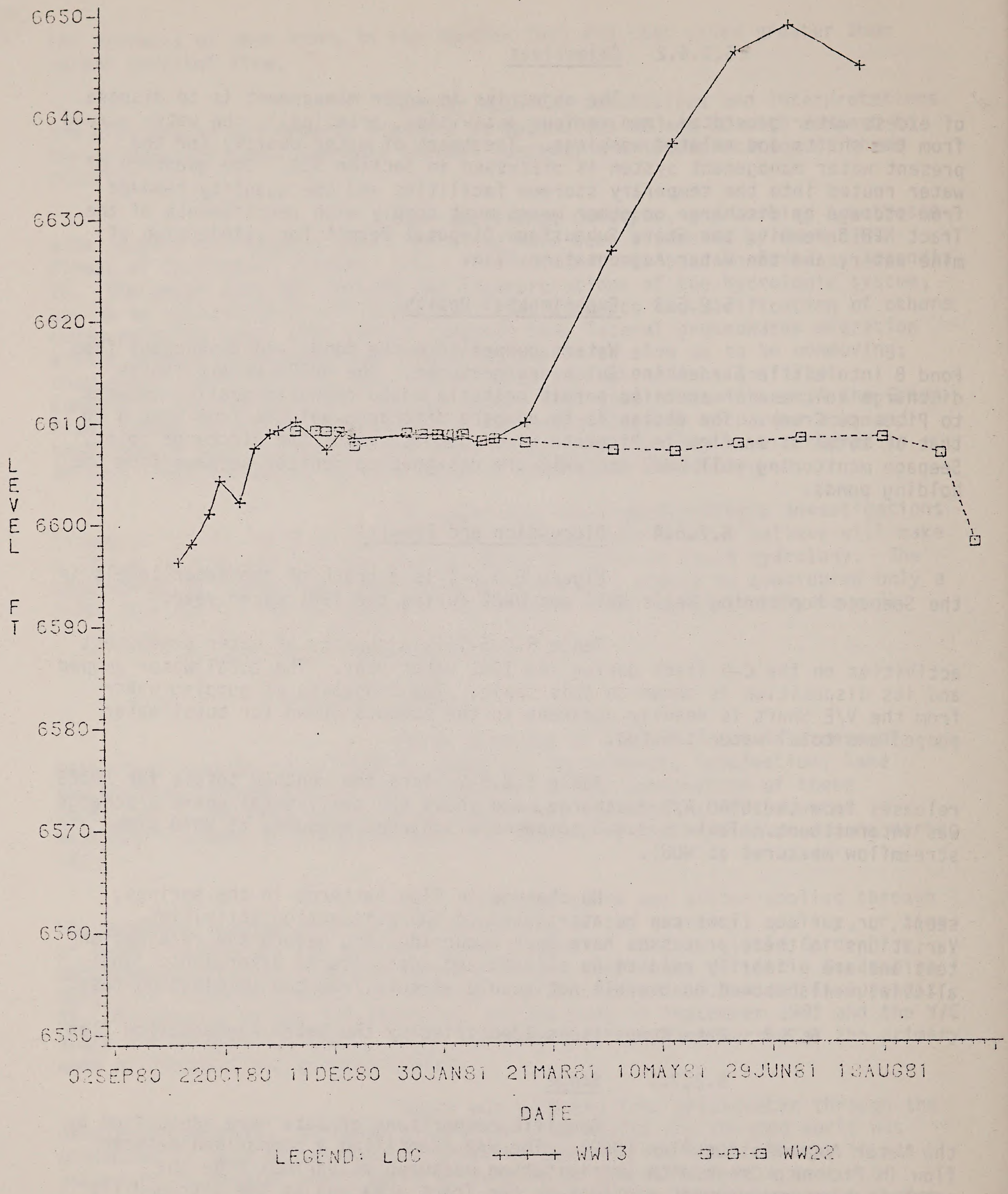


FIGURE 5.2.6-1

LEVELS DURING THE 1981 WATER YEAR FOR SEEPAGE MONITORING WELLS WW13 AND WW22

TABLE 5.2.6-1

SUMMARY OF WATER MANAGEMENT (gpm)

Month	Total Water Pumped	Water Used Stored, Evaporated	Water Treated			
			NPDES Discharges	Sprinkler (Land Application)	Reinjection	Total
January	1,645	341	1,304	-	-	1,304
February	1,663	596	1,067	-	-	1,067
March	1,392	498	754	-	140	894
April	1,122	278	583	-	261	844
May	1,636	466	1,109	-	61	1,170
June	1,221	136	745	48	292	1,085
July	1,582	467	739	339	37	1,115
August	1,550	275	942	326	7	1,275
September	617*	180	293	39	105	437
October	627	184	8	-	435	443
November	660	205	16	-	439	455
December	772	298	-	-	474	474

*Starting September 3, 1981 V/E Shaft no longer pumped

TABLE 5.2.6-2 MONTHLY TOTAL DISCHARGE FROM WN40

January	58,200,000	Gallons
February	43,030,000	"
March	33,670,000	"
April	25,200,000	"
May	49,505,760	"
June	32,184,000	"
July	32,999,599	"
August	42,040,000	"
September	12,657,600	"
October	357,120	"

TABLE 5.2.6-3 COMPARISON BETWEEN MEAN FLOWS FROM WN40 DISCHARGE AND WU61 STREAMFLOW

	WN40 Mean Discharge CFS	WU61 Mean Flow CFS	$\frac{WN40}{WU61}$ *100
Oct	*		
Nov	*		
Dec	*		
Jan	2.90	606	0.48
Feb	2.38	490	0.49
Mar	1.68	499	0.34
Apr	1.30	385	0.34
May	2.47	219	1.13
Jun	1.67	168	0.99
Jul	1.65	208	0.79
Aug	2.10	270	0.78
Sep	0.65	101	0.64

*Data not available

at the Little Hills Station, WR01, were identified as measurements to compare with the flows on Piceance Creek upstream at WU07 and downstream from the Tract at WU61. Flow data from springs WS31, WS32, and WS34 were specifically identified by the Water Augmentation Plan. The measurements of levels in WX12 were also identified. The possibility of correlation between precipitation measurements at AB20 or AB23 and Piceance Creek wintertime flow as measure at either WU00 or WU07 was also identified by the Water Augmentation Plan.

5.2.7.2 Methods of Analysis

Comparisons between data sets were done using linear regression analysis or lagged linear regression analysis. Time sequence plots of flow from springs or levels in wells were also prepared for qualitative analysis.

5.2.7.3 Discussion and Results

Monthly precipitation amounts measured at AB20, AB23 and WR01, were shown in Section 6.0 and flow measurements at WU00, WU61 and WU07 were shown in Section 5.2.2. Histograms of wintertime flow averaged over December and January are presented on Figure 5.2.7-1 for WU00, WU07, WU22 and WU61.

Table 5.2.7-1 summarizes the results of the correlation analyses between precipitation and flow in Piceance Creek. As indicated in the table, precipitation measured at Little Hills shows poor correlation with Piceance Creek flow. This lack of correlation indicates that in areas with marked spatial variability in precipition events, precipitation measurements do not correlate well with streamflows unless the gauge is placed within the known area of contribution to the water course. Results from lagged correlations showed no improvement over unlagged results.

The time sequence graphs of flow data from springs WS31, WS32 and WS34 were previously shown on Figure 5.2.2-7. The upper aquifer well WX12 was recompleted as a UPC1 monitor, WD12. Figure 5.2.7-2 is the time sequence graph of levels measured in WD12.

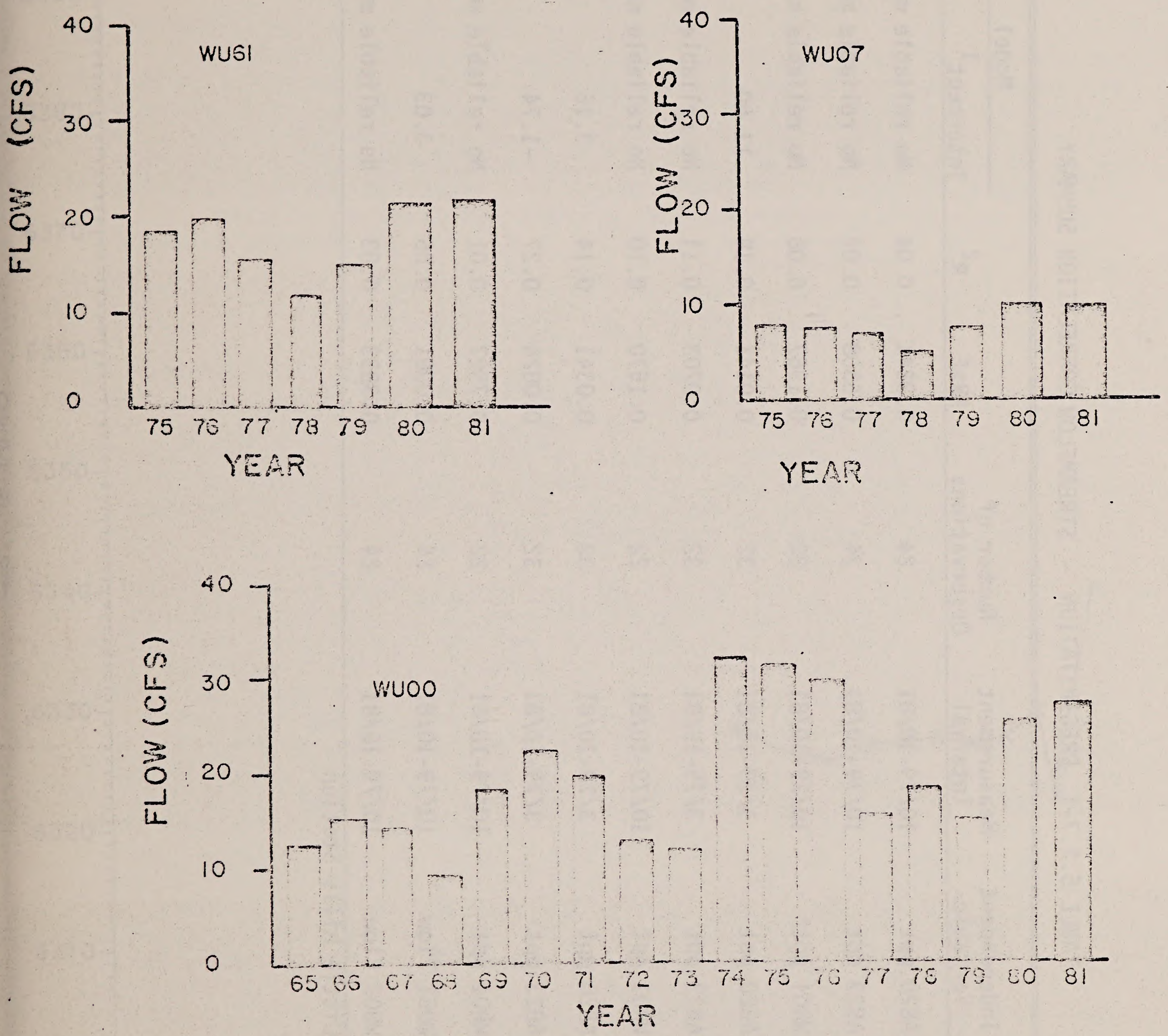
5.2.8 Hydrogeologic Studies During Shaft Sinking

5.2.8.1 Scope

Geologic and hydrologic studies of the Piceance Basin have taken place over the past 50 years based on core data, well log data, outcrop data, and subsurface mapping in the mines that exist around the perimeter of the basin. The subsurface geology and hydrology were inferred from these data. The sinking of three large diameter shafts at C.B. presented a unique opportunity to map the entire vertical geologic section of the Uinta formation from the surface to the mid R-5 Zone and to observe and record the natural groundwater conditions that exist before the advent of mining and dewatering.

FIGURE 5.2.7-1

HISTOGRAMS OF WINTERTIME
MEAN FLOW* FOR SELECTED USGS GAUGING
STATIONS ON PICEANCE CREEK



$* \left(\frac{\text{DEC. FLOW + JAN. FLOW}}{2} \right)$

TABLE 5.2.7-1 PRECIPITATION - STREAMFLOW CORRELATION SUMMARY

Dependent Variable	Independent Variable	Measurement Interval	Number of Observations	PR>F	R^2	Model Intercept[1]	Model Slope[2]
WU00 Flow	AB20 ppt	10/79-10/81	24	0.3341	0.04	No reliable model	
WU00 Flow	AB23 ppt	10/79-10/81	24	0.5508	0.02	No reliable model	
WU00 Flow	WR01 ppt*	10/79-10/81	22	0.1967	0.08	No reliable model	
WU61 Flow	AB20 ppt	3/79-10/81	32	0.0141	0.18	11.60	12.96
WU61 Flow	AB23 ppt	3/79-10/81	32	0.0703	0.11	No reliable model	
WU61 Flow	WR01 ppt	10/79-10/81	22	0.1570	0.10	No reliable model	
WU07 Flow	AB20 ppt	3/79-10/81	32	0.0341	0.14	3.16	10.04
WU07 Flow	AB23 ppt	3/79-10/81	32	0.0024	0.27	-1.74	15.97
WU07 Flow	WR01 ppt	10/79-10/81	22	0.7527	0.01	No reliable model	
WU00 Flow	WU61 Flow	10/79-10/81	24	0.0001	0.86	3.03	0.93
WU00 Flow	WU07 Flow	10/79-10/81	24	0.3833	0.03	No reliable model	

*WR01 is the Little Hills Station

[1] CFS

[2] CFS/CM

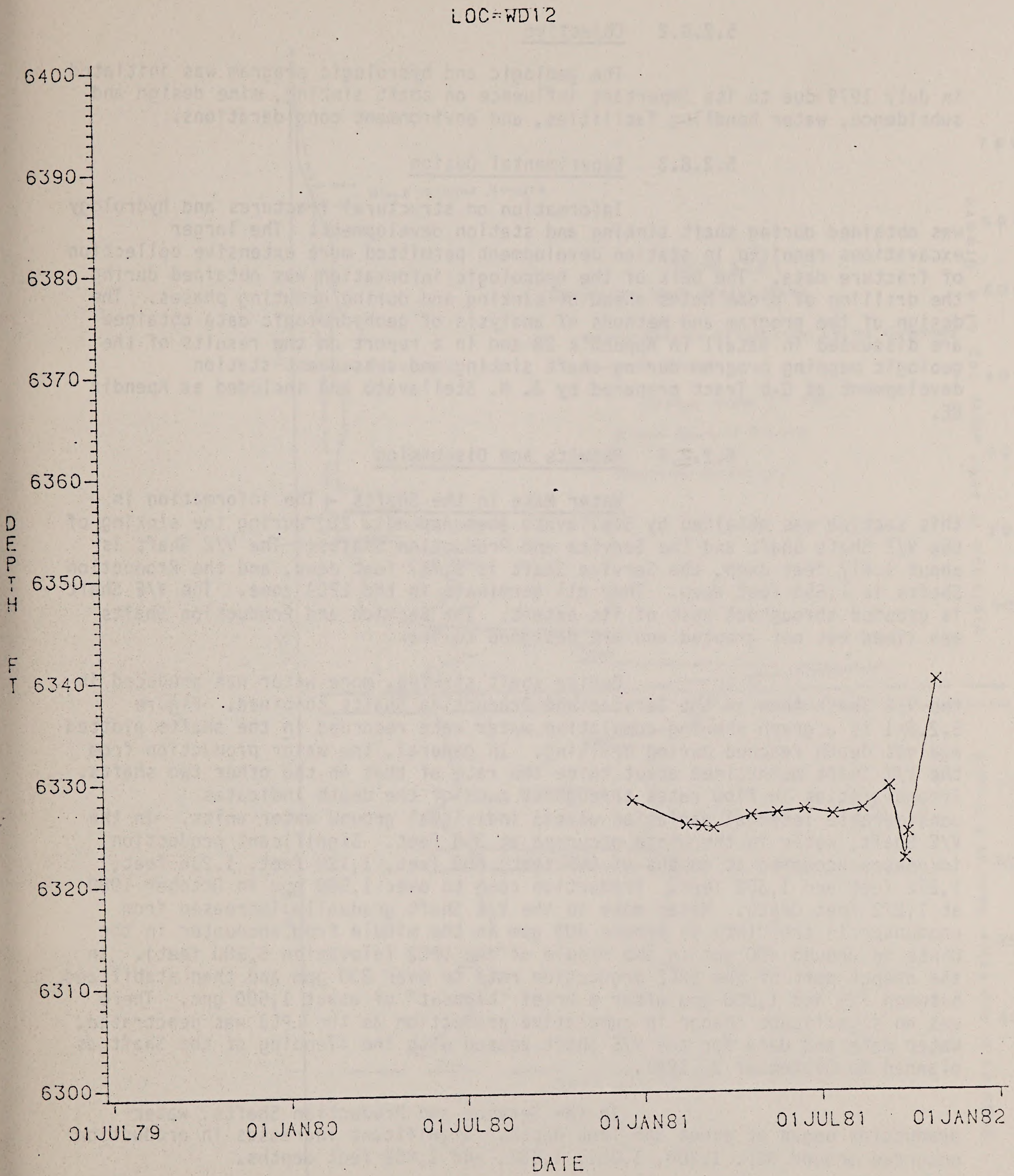


FIGURE 5.2.7-2

TIME SERIES OF LEVELS DATA WD12

5.2.8.2 Objective

The geologic and hydrologic program was initiated in July 1979 due to its important influence on shaft sinking, mine design and subsidence, water handling facilities, and environment considerations.

5.2.8.3 Experimental Design

Information on structural fractures and hydrology was obtained during shaft sinking and station development. The larger excavations required in station development permitted more extensive collection of fracture data. The bulk of the hydrologic information was obtained during the drilling of probe holes ahead of sinking and during grouting phases. The design of the program and methods of analysis of geohydrologic data obtained are discussed in detail in Appendix 2B and in a report on the results of the geologic mapping program during shaft sinking and subsequent station development at C-b Tract prepared by J. N. Stellavato and included as Apendix 2E.

5.2.8.4 Results and Discussion

Water Make in the Shafts - The information in this section was obtained by Stellavato (see Appendix 2E) during the sinking of the V/E Shaft Shaft and the Service and Production Shafts. The V/E Shaft is about 1,617 feet deep, the Service Shaft is 1,757 feet deep, and the Production Shafts is 1,856 feet deep. They all terminate in the LPC4 zone. The V/E Shaft is grouted throughout most of its extent. The Service and Production Shafts are lined but not grouted and are designed to leak.

During shaft sinking, more water was produced in the V/E Shaft than in the Service and Production Shafts combined. Figure 5.2.8-1 is a graph showing cumulative water rate recorded in the shafts plotted against depth reached during drilling. In general, the water production from the V/E Shaft maintained about twice the rate of that in the other two shafts. Irregularities in flow rates throughout much of the depth indicates considerable internal variation within individual ground water units. In the V/E Shaft, water in the Uinta occurred at 350 feet. Significant production increases occurred at depths of 665 feet, 809 feet, 1,120 feet, 1,216 feet, 1,272 feet and 1,302 feet. Production rose to over 1,500 gpm in October 1980 at 1,272 feet depth. Water make in the V/E Shaft gradually increased from encounter in the Uinta to around 400 gpm in the middle from encounter in the Uinta to around 400 gpm in the middle of the UPC2 (elevation 5,580 feet). In the deeper part of the UPC2 production rose to over 830 gpm and then stabilized between 725 and 1,000 gpm after a brief "blowout" of about 1,600 gpm. There was no significant change in cumulative production as the LPC3 was penetrated. Water make and data for the V/E Shaft ceased with the flooding of the Shaft as planned in September 2, 1981.

In the Service and Production Shafts, water production began at about 365 feet depth. Significant increases in production occurred around 889, 1,200, 1,281, 1,531, and 1,852 feet depths.

Water make in the Service and Production Shafts gradually increased with the depth of the shafts from near zero to about 575

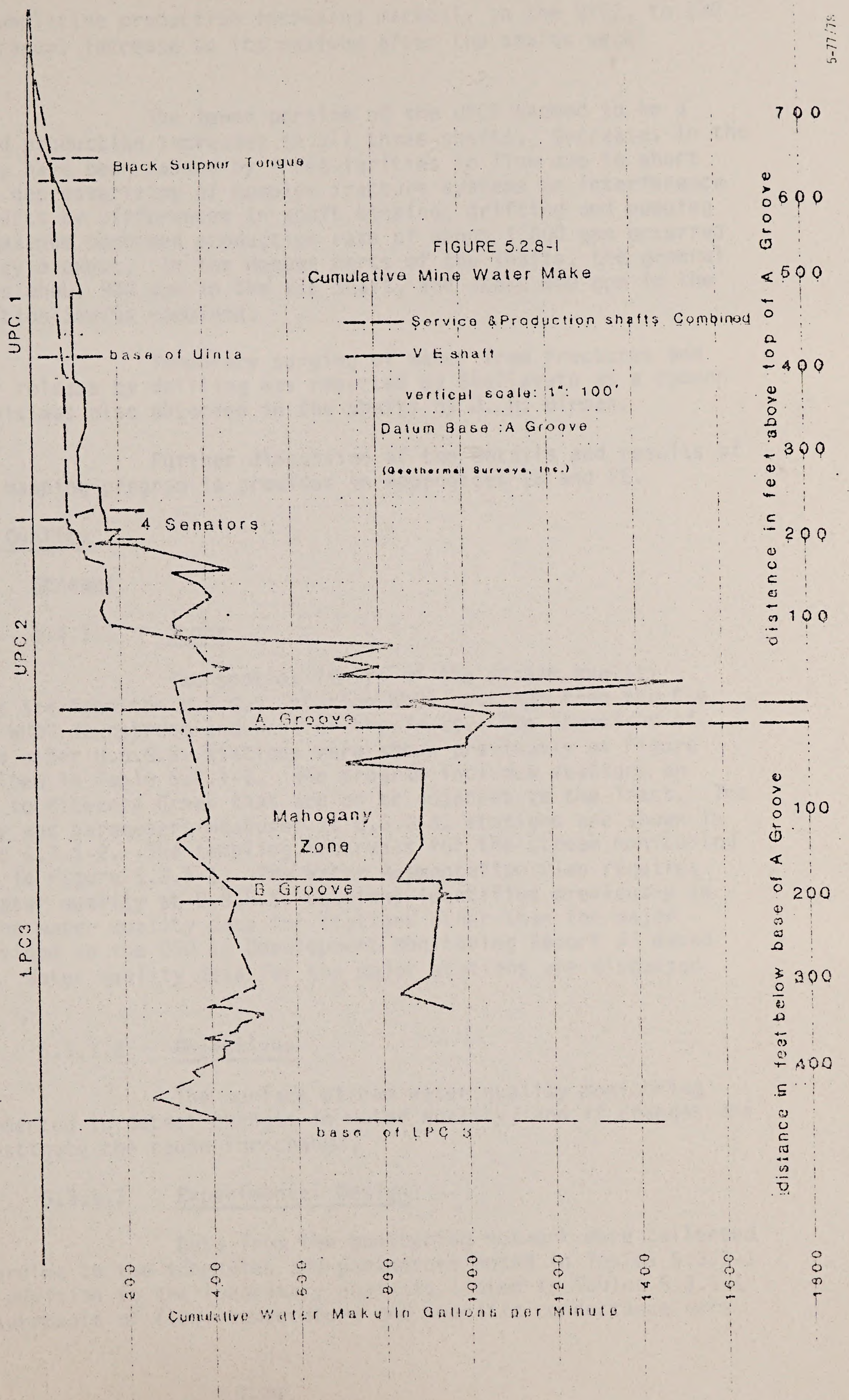


FIGURE 5.2.8-1
Cumulative Mine Water Make

5-77/78

gpm. Again, the cumulative production increased markedly in the UPC2, to 230 gpm and showed a gradual increase to its maximum after the shafts were completed.

The lower portion of the UPC2 seemed to be a threshold to marked production increases in all three shafts. Decreases in the production rate may have been caused by irregularities in flow due to short term dewatering or depressurizing of complex fracture systems or interference among the three shafts by differences in shaft sinking, drifting and pumping activities. The maximum combined production rate of about 1,600 gpm occurred during the temporary blowout. In the deeper parts of the shafts, the general production rate was about 900 gpm in the V/E Shaft, and about 500 gpm in the Service and Production Shafts combined.

Temporary surging of water from fractures and vugs shortly after release by drilling was reported by Stellavato as a common occurrence, and this was also observed in the shafts by J. H. Birman.

Further discussion of the details and results of the geohydrologic mapping program is provided in Appendices 2B and 2E.

5.3 Water Quality

5.3.1 Streams

5.3.1.1 Scope

The spatial limits of the stream quality monitoring program are from the U.S.G.S. station WU07 upstream from the C-b Tract to U.S.G.S. WU00 downstream and west of the Tract. The locations of these stations and other U.S.G.S. stations were shown previously on Figure 5.2.1-1 and described in Table 5.2.1-1. The program includes stations on streams tributary to Piceance Creek that are on or adjacent to the Tract. The sampling frequency and parameters measured at U.S.G.S. stations are shown in Tables 5.3.1-1 and 5.3.1-2. The sampling intervals for the stream monitoring program are shown in Figure 5.3.1-1. The Water Augmentation Plan requires measurements of water quality at U.S.G.S. stations identified previously in Table 5.2.1-1. The water quality data for stations other than the major stations were provided to the OSO in Development Monitoring Report #7 dated January 15, 1982. Water quality data for the major stations are discussed below.

5.3.1.2 Objectives

The surface stream water quality monitoring program was implemented to detect changes in water quality, and if changes are detected, to investigate the cause for change.

5.3.1.3 Experimental Design

Data from the monitoring network were collected and analyzed according to the schedules and parameters noted in Tables 5.3.1-1 and 5.3.1-2. In addition to the laboratory analysis listed in Tables 5.3.1-1 and 5.3.1-2, measurements of flow, temperature and specific conductance were

TABLE 5.3.1-1

WATER SAMPLING FREQUENCY REQUIREMENTS
MAJOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$			●				
MO Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al				●			
Ammonia	as NH_3			●				
Antimony								
Arsenic	As			●				
Bacteria	Sb							
Barium	Ba				●			
Beryllium	Be							
Bicarbonate	HCO_3			●				
Biological Oxygen Demand	BOD				●			
Bismuth	Bi							
Boron	B			●				
Bromine	Br				●			
Cadmium	Cd				●			
Calcium	Ca			●				
Carbonate	CO_3			●				
Chemical Oxygen Demand	COD				●			
Chloride	Cl			●				
Chromium	Cr				●			
Cobalt	Co							
Coliform, Fecal					●			
Coliform, Total					●			
Color (Not Precise)								
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC	●						
Copper	Cu				●			
Cyanide	Cn				●			
Dissolved Oxygen	OO							
Element Scan					●			
Fecal Streptococcus					●			
Flow		●						
Fluoride	F			●				
Gallium	Ga							
Germanium	Ge							
Hardness (Ca, Mg)								
Hydroxides	OH							
Iodine	I							
Iron	Fe			●				
Kjeldahl Nitrogen				●				
Lead	Pb				●			
Level								
Lithium	Li				●			
Magnesium	Mg			●				
Manganese	Mn			●				
Mercury	Hg				●			
Methylene Blue Active Substance	MBAS					●		
Molybdenum	Mo				●			
Nickel	Ni							
Nitrate	NO_3			●				
Nitrite	NO_2			●				
Odor								
Oil & Grease	OLGR				●			
Organic Carbon, Dissolved	DOC			●				
Organic Carbon, Total	TOC			●				
Ortho-Phosphorus (Phosphate)	PO_4				●			
Pesticides						●		
pH	pH	●						
Phenols				●				
PNA	PNA							
Potassium	K			●				
Rubidium	Rb							
Sediment Characterization								
Selenium	Se				●			
Scandium	Sc							
Silica	SiO_2			●				
Silver	Ag							
Sodium	Na			●				
Solids, Dissolved	TDS			●				
Solids, Suspended	TSS							
Strontium	Sr				●			
Surfactants								
Sulfate	SO_4			●				
Sulfide	SO_2				●			
Temperature (°C)		●						
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti							
Tungsten	W							
Turbidity		▲						
Vandium	V							
Yttrium	Y							
Zinc	Zn				●			
Zirconium	Zr							
Radioactivity								
Gross Alpha (pcl)					●			
Radium 226	Ra226							
Natural Uranium	U							
Gross Beta					●			
Cesium	Ce137							
Sr90								
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. Hydrophobic Bases						●		
b. Hydrophobic Acids						●		
c. Hydrophobic Neutrals						●		
d. Hydrophilic Bases						●		
e. Hydrophilic Acids						●		
f. Hydrophilic Neutrals						●		

* USGS Major stations WU00, WU07, WU22, WU42, WU43, WU58, WU61, WU62.

SYMBOLS:

- ● Applies to all stations.
- ▲ Applies to stations WU07 and WU01 only.

TABLE 5.3.1-2

WATER SAMPLING FREQUENCY REQUIREMENTS
MINOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$			●			
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_3			●			
Antimony							
Arsenic	As			●			
Bacteria	Sb						
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3			●			
Biological Oxygen Demand	BOD				●		
Bismuth	Bi						
Boron	B			●			
Bromine	Br				●		
Cadmium	Cd				●		
Calcium	Ca			●			
Carbonate	CO_3			●			
Chemical Oxygen Demand	COD				●		
Chloride	Cl			●			
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal					●		
Coliform, Total					●		
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC	●					
Copper	Cu				●		
Cyanide	Cn				●		
Dissolved Oxygen	DO						
Element Scan					●		
Fecal Streptococcus					●		
Flow		●					
Fluoride	F			●			
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe			●			
Kjeldahl Nitrogen				●			
Lead	Pb				●		
Level							
Lithium	Li				●		
Magnesium	Mg			●			
Manganese	Mn			●			
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS					●	
Molybdenum	Mo				●		
Nickel	Ni						
Nitrate	NO_3			●			
Nitrite	NO_2			●			
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC			●			
Organic Carbon, Total	TOC			●			
Ortho-Phosphorus (Phosphate)	PO_4				●		
Pesticides						●	
pH	pH	●					
Phenols				●			
PNA	PNA						
Potassium	K			●			
Rubidium	Rb						
Sediment Characterization							
Selenium	Se				●		
Scandium	Sc						
Silica	SiO_2			●			
Silver	Ag						
Sodium	Na			●			
Solids, Dissolved	TDS			●			
Solids, Suspended	TSS						
Strontium	Sr				●		
Surfactants							
Sulfate	SO_4			●			
Sulfide	SO_2				●		
Temperature (°C)		●					
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity		▲					
Vandium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)					●		
Radium 226	Ra226						
Natural Uranium	U						
Gross Beta					●		
Cesium	Ce137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* USGS Minor stations WU15, WU25, WU28, WU33, WU36, WU39, WU45, WU50, WU52, WU55.

SYMBOLS:

● Applies to all stations.

▲ Applies to stations WU07 and WU61 only.

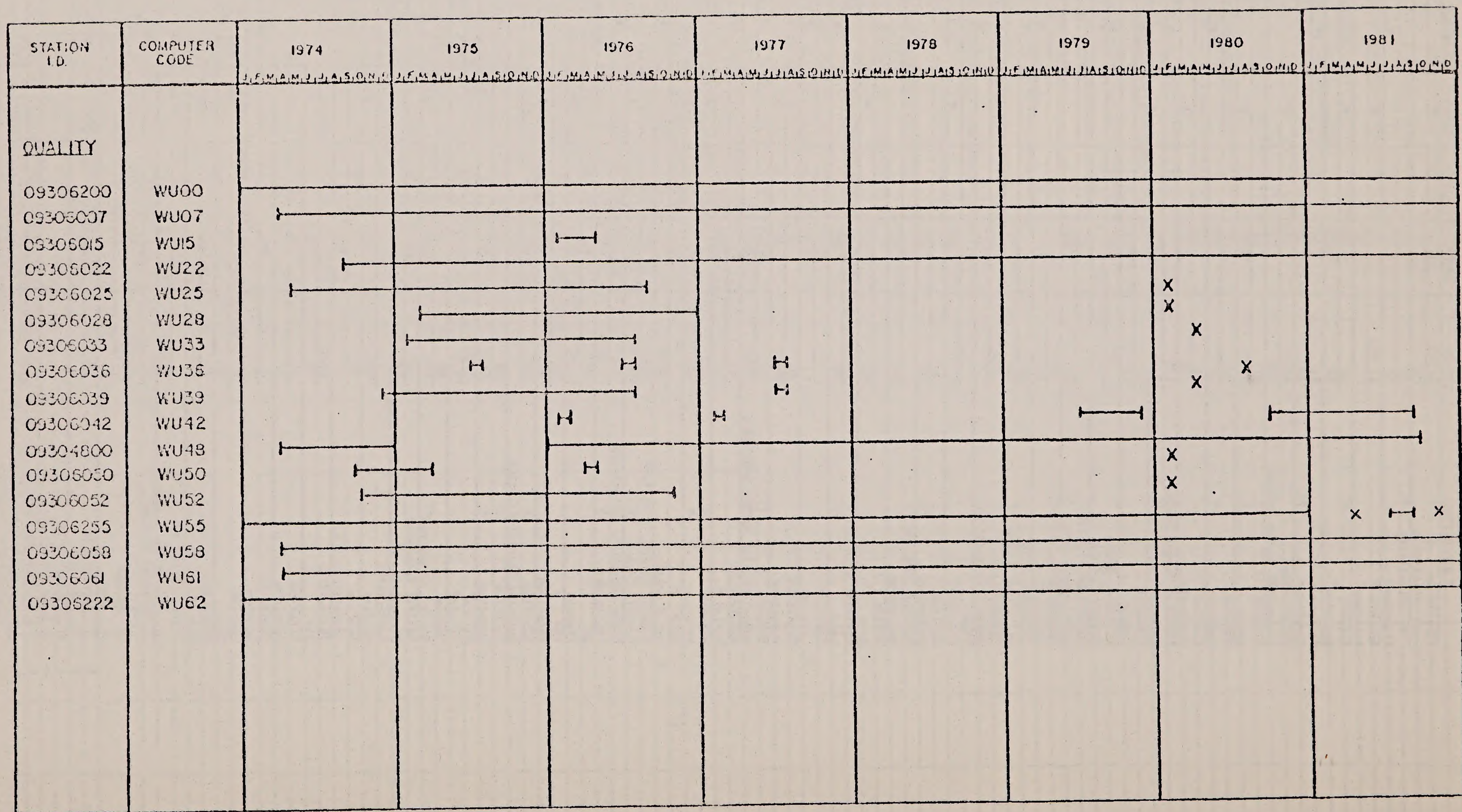


FIGURE 5.3.1-1
U.S.G.S. STREAM GAUGING STATIONS
SAMPLING TIME INTERVALS
FOR WATER QUALITY

made at all stations. At two of the four major stations on perennial streams, pH and dissolved oxygen are measured and recorded, i.e., at the two Piceance Creek stations. Suspended sediment samples are obtained at Stations WU07, WU22, WU39, WU58 and WU61. All water quality samples are analyzed by procedures previously used during the Environmental Baseline Study. Analysis and data verification for the U.S.G.S. stations are performed by the U.S.G.S. laboratories in Denver and by the U.S.G.S. Subdivision office in Meeker.

5.3.1.4 Methods of Analysis

Linear regression modeling was used as an initial screening technique to test for the existence of linear trends with time. Histograms were also used for the analyses of stream quality data. Histogram comparisons were used to compare variables for stations over time as well as station to station comparisons of variables during the same time interval.

5.3.1.5 Discussion and Results

Table 5.3.1-3 lists mean, maximum and minimum values for selected water quality parameters during the 1981 water year. These values were from the four major stream gauging stations and for WU42, which monitors effluent discharges from C-b into Piceance Creek. Histograms or time sequence graphs of these parameters have been provided to the OSO in the time series supplement to Development Monitoring Report #7, dated February 1982. As the table shows, the maxima and minima are distributed throughout the year, and dates vary by constituent. The chemistry of Piceance Creek is a function of natural flow conditions for the most part, but may also be affected by irrigation diversions.

Table 5.3.1-4 compares baseline mean values for major constituents and the mean values for the 1981 water year at the major stations. Ratios of constituent concentrations at WU61 and WU07 are presented in Table 5.3.1-5. A major difference in these ratios is found in the fluoride concentration at WU61. Section 5.3.6 discusses parameters analyzed for NPDES compliance.

Table 5.3.1-6 shows the results of the application of a linear regression model to the water quality data from major U.S.G.S. stations. Four items are shown and are identified in the table footnotes: mean and number of observations, the alpha level to be compared with the selected alpha of 0.05, the slope of the regression line, and the r-square value. The omission of items three and four indicates that the linear model did not fit the data at the 0.05 level of significance. Short-term linear trends were shown in temperature at all four stations. Short-term linear trends in conductivity and ammonia concentration occurred at three of the four stations. The slopes of the regression lines for ammonia concentrations with time are near zero for all three stations. No short-term linear trends with time were shown for arsenic, boron, fluoride, sodium, or total dissolved solids.

TABLE 5.3.1-3

MEAN, MAXIMUM AND MINIMUM VALUES FOR SELECTED CONSTITUENTS SURFACE WATER, TRACT C-b (mg/l)

Station	TDS		Mg		Ca		Na		SO_4		Alk		B		F	
WU07																
Mean	746		49		71		133		192		560		.22		.99	
Max	836	6-9	54	6-9	79	2-11	150	4-15	230	6-9	520	9-25	.26	7-7	1.7	12-10
Min	673	1-23	43	1-23	65	1-23	120	12-10	160	12-10	420	11-19	.19	3-3	.4	10-14
WU61																
Mean	959		61		68		191		307		536		.25		2.3	
Max	1060	6-9	74	9-15	76	9-15	230	2-11	350	6-9	580	6-23	.31	2-11	4.8	1-13
Min	886	1-23	52	1-23	63	2-11	170	10-14	260	12-10	500	11-19	.18	10-14	.6	10-14
WU22																
Mean	906		72		87		123		359		•		.10		.3	
Max	948	7-7	74	10-14	92	5-12	130	10-14	440	2-11	•		.27	7-7	.5	12-10
Min	870	2-11	69	12-10	81	10-14	100	2-11	330	11-4	•		.07	2-11	.2	10-14
WU42																
Mean	1413		7.1		12		522		288		•		.79		16	
Max	1580	10-14	7.7	8-4	17	10-14	580	10-23	490'	10-14	•		.84	2-11	19	1-13
Min	1220	8-4	5.6	1-13	9.9	6-9	480	7-1	91	8-4	•		.55	10-14	15	1-23
WU58																
Mean	848		69		84		119		316		435		.13		.5	
Max	948	7-7	72	5-12	93	5-12	140	7-7	380	7-7	460	6-23	.32	7-7	.7	12-10
Min	779	11-4	62	11-4	76	1-23	110	11-4	280	11-4	420	11-19	.10	1-13	.2	10-14

TABLE 5.3.1-4

Comparisons of 1981 Water Year vs. Baseline
for Mean Values of Major Water Quality Constituents
Values are in mg/l

Baselines are mean values

	WU07		WU22		WU58		WU61	
	1980-1981	Baseline	1980-1981	Baseline	1980-1981	Baseline	1980-1981	Baseline
Alk	460	422	-	403	435	402	538	465
NH_3	0.06	0.04	0.07	0.02	0.06	0.02	0.09	0.03
As	0.0026	0.0024	0.0015	0.0010	0.0016	0.0011	0.0027	0.0023
B	0.218	0.209	0.095	0.108	0.133	0.210	0.245	0.214
Ca	71	69	87	93	84	92	68	78
Cl	16.3	15	6.5	7.2	12.2	11.5	11.6	14
F	1.0	0.9	0.3	0.3	0.4	0.4	2.2	0.9
Mg	49	46	72	76	69	76	62	67
Mn	92	46	9	10	8	14	43	66
DOC	-	-	-	-	-	-	-	-
K	2.8	3.6	1.3	1.6	1.6	2.2	2.9	3.5
Si	16	15	16	15	16	15	19	17
Na	134	122	123	124	119	128	191	150
TDS	750	692	905	936	851	926	963	902
SO_4	193	164	359	368	318	356	309	290

Station values in 1980-1981 are for the months of 10/80 to 9/81 from USGS water data.

Baseline values are for the period 11/74 to 10/76 - from environmental baseline program.

TABLE 5.3.1-5

Downstream-to-Upstream* Ratios
of 12-Month Means, October 1-October 1

	1979-1980, WU61/WU07	1980-1981 WU61/WU07	Baseline, WU61/WU07
Alk	1.06	1.17	1.10
NH_3	1.75	1.43	0.75
As	0.97	1.03	0.96
B	1.02	1.12	1.02
Ca	1.03	0.95	1.13
Cl	0.99	0.71	0.93
F	1.00	2.23	1.00
Mg	1.20	1.26	1.46
Mn	0.76	0.47	1.43
K	1.09	1.05	0.97
Si	1.00	1.20	1.13
Na	1.15	1.43	1.23
SO_4	1.36	1.61	1.77
TDS	1.17	1.28	1.30

*Station WU61 is on Piceance Creek, downstream of the Tract;
Station WU07 is on Piceance Creek, upstream of the Tract.

TABLE 5.3.1-6

Short-Term Regression Analysis for Major U.S.G.S. Stations for Water Year 1981

Dependent Variable		WU07	WU22	WU58	WU61
Temperature (°C)	1.	8.1/10	7.7/19	7.8/10	8.1/10
	2.	0.0081	0.0301	0.0087	0.0125
	3.	0.0456	0.0167	0.0429	0.0399
	4.	0.61	0.51	0.60	0.56
Conductivity (umhos)	1.	1105/10	1319/10	1251/9	1376/10
	2.	0.1525	0.0239	0.0135	0.0179
	3.	-	0.1746	0.6837	0.5122
	4.	-	0.49	0.61	0.52
DOC (mg/l)	1.	9.05/10	9.12/10	9.31/10	9.17/10
	2.	0.0287	0.9046	0.0921	0.1170
	3.	-0.0062	-	-	-
	4.	0.47	-	-	-
pH	1.	8.33/10	8.29/10	8.28/10	8.29/10
	2.	-	0.0436	0.3178	0.6753
	3.	-	0.0008	-	-
	4.	-	0.42	-	-
NH_3 (mg/l)	1.	0.06/12	0.07/12	0.06/12	0.09/12
	2.	0.2096	0.0179	0.0110	0.0621
	3.	-	-0.0002	-0.0003	0.0002
	4.	-	0.44	0.49	0.31
As (mg/l)	1.	2.58/12	1.50/12	1.5/12	2.67/12
	2.	0.2071	0.1500	0.4007	0.1715
	3.	-	-	-	-
	4.	-	-	-	-
B (mg/l)	1.	0.22/12	0.10/12	0.13/12	0.25/12
	2.	0.5719	0.5200	0.6097	0.1615
	3.	-	-	-	-
	4.	-	-	-	-
F (mg/l)	1.	0.98	0.31	0.44	2.19
	2.	0.9037	0.52.38	0.8530	0.4253
	3.	-	-	-	-
	4.	-	-	-	-
Na (mg/l)	1.	134/12	123/1212	119/12	191/12
	2.	0.4885	0.5884	0.3015	0.6789
	3.	-	-	-	-
	4.	-	-	-	-
TDS (mg/l)	1.	750/12	905/12	851/12	963/12
	2.	0.2303	0.3695	0.0706	0.0523
	3.	-	-	-	-
	4.	-	-	-	-
SO_4 (mg/l)	1.	193/12	359/12	318/12	309/12
	2.	0.0453	0.6880	0.0495	0.0694
	3.	0.1189	-	0.1576	-
	4.	0.34	-	0.33	-

1. Mean/no of observations; 2. Alpha level (significant if less than 0.05); 3. slope per day; 4. r-square.

5.3.2 Springs

5.3.2.1 Scope

As discussed in Section 5.2.2, there is a substantial contribution to Piceance Creek by springs during periods of low streamflow.

Water quality data were gathered during the baseline phase, and new springs were added by the requirements of the Water Augmentation Plan. Spring locations were shown previously as Figure 5.2.2-1. Parameters and sampling frequency for water quality of springs are shown in Table 5.3.2-1, and sampling intervals are shown in Table 5.3.2-2.

5.3.2.2 Objectives

Objectives in monitoring the water quality of springs are to provide data for the investigation of spring sources, for the investigation of changes or trends in spring water quality, and to determine whether these changes are related to C-b Tract development.

5.3.2.3 Experimental Design

Water quality data from springs were obtained according to the sampling frequency for the parameters shown on Table 5.3.2-1. These data were analyzed using linear regression modeling with respect to time to determine if trends existed. Time sequence graphs were prepared for those parameters that were shown to have trends with time by the linear regression modeling analysis.

5.3.2.4 Results and Discussion

The results of the linear regression of water quality parameters with respect to time are provided as Table 5.3.2-3. Graphs of the parameters that showed linear trends are as Figures 5.3.2-1 through 5.3.2-7.

Temperature measurements displayed the characteristic annual pattern in all springs. WS08 showed a decline in pH, but with the slope of the regression near zero. Sodium measurements showed a decrease since 1978 until early 1980. Values have increased since then, but remain within normal variability. Sulfate data show periodic fluctuations with a low point in September of 1980 and increasing since that time. Ammonia values have decreaed in WS06 since 1979, and boron levels in WS01, WS03, and WS04 show decrease with regression line slopes near zero. Molybdenum in WS09 shows decrease in its very low values with regression slope near zero.

5.3.3 Alluvial Wells

5.3.3.1 Scope

Alluvial wells were drilled in all gulches at C.B. and in the major drainages of Piceance Creek, Willow Creek, and Stewart Gulch as described in Section 5.2.3.1. The locations of the wells were shown previously in Figure 5.2.3-1. Water quality parameters and frequency of

TABLE 5.3.2-1

WATER SAMPLING FREQUENCY REQUIREMENTS
SPRINGS AND SEEPS STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$				●			
MO Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al				●			
Ammonia	as NH_3				●			
Antimony					●			
Arsenic	As				●			
Bacteria	Sb							
Barium	Ba				●			
Beryllium	Be							
Bicarbonate	HCO_3				●			
Biological Oxygen Demand	BOD				●			
Bismuth	Bi							
Boron	B				●			
Bromine	Br						●	
Cadmium	Cd				●			
Calcium	Ca				●			
Carbonate	CO_3				●			
Chemical Oxygen Demand	COD				●			
Chloride	Cl				●			
Chromium	Cr				●			
Cobalt	Co							
Coliform, Fecal						●		
Coliform, Total						●		
Color (Not Precise)								
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC			●				
Copper	Cu				●			
Cyanide	Cn							
Dissolved Oxygen	DO			●				
Element Scan								
Fecal Streptococcus						●		
Flow			■					
Fluoride	F				●			
Gallium	Ga							
Germanium	Ge							
Hardness (Ca, Mg)					●			
Hydroxides	OH							
Iodine	I							
Iron	Fe				■			
Kjeldahl Nitrogen					●			
Lead	Pb				●			
Level					●			
Lithium	Li				●			
Magnesium	Mg				●			
Manganese	Mn				●			
Mercury	Hg				●			
Methylene Blue Active Substance	MBAS							
Molybdenum	Mo				●			
Nickel	Ni				●			
Nitrate	NO_3				●			
Nitrite	NO_2				●			
Odor								
Oil & Grease	OLGR				●			
Organic Carbon, Dissolved	DOC					▲		
Organic Carbon, Total	TOC							
Ortho-Phosphorus (Phosphate)	PO_4							
Pesticides								
pH	pH			●				
Phenols					●			
PNA	PNA							
Potassium	K				●			
Rubidium	Rb							
Sediment Characterization								
Selenium	Se				●			
Scandium	Sc							
Silica	SiO_2							
Silver	Ag							
Sodium	Na				●			
Solids, Dissolved	TDS							
Solids, Suspended	TSS				●			
Strontium	Sr				●			
Surfactants								
Sulfate	SO_4				●			
Sulfide	SO_2							
Temperature (°C)				●				
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti							
Tungsten	W							
Turbidity								
Vandium	V							
Yttrium	Y							
Zinc	Zn				●			
Zirconium	Zr							
Radioactivity								
Gross Alpha (pCl)						●		
Radium 226	Ra226					●		
Natural Uranium	U							
Gross Beta						●		
Cesium	Cs137							
Sr90								
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. Hydrophobic Bases								
b. Hydrophobic Acids								
c. Hydrophobic Neutrals								
d. Hydrophilic Bases								
e. Hydrophilic Acids								
f. Hydrophilic Neutrals								

* Springs stations WS01 thru WS10, WS21 thru WS30, WS37.

SYMBOLS:
- ● Applies to stations WS01 thru WS10
- ▲ Applies to two stations to be selected by OSO.
- ■ Applies to all stations.

TABLE 5.3.2-2

SPRINGS
SAMPLING TIME INTERVALS
FOR QUALITY

COMPUTER CODE	1974	1975	1976	1977	1978	1979	1980	1981
*S01	1		3	1	1	3	4	3
*S02	1	1	2		2	3	4	4
*S03	1	1	7	1	4	3	4	3
*S04	1	1	1		2	3	4	4
*S06	1	2	2	1	2	3	4	4
*S07	1	1	2	1	3	3	4	4
*S08	1	1	1		1	1	3	1
*S09	1	1	8	1	2	3	4	4
*S10	1	2	4	1	2	3	4	4
*S11		1					2	4
*S12							2	4
*S35							3	4
*S56							1	

TABLE 5.3.2-3

Long-Term Time Series Analysis for Water Quality of Springs & Seeps

	Mean	Of Observations	$\hat{\alpha}$	Slope/Per Day	r^2
		Temperature °C			
WS01	8.7	12	0.0198	0.0069	0.43
WS02	8.5	13	0.0035	0.0066	0.55
WS03	6.9	19	0.0017	0.0073	0.45
WS04	9.0	12	0.0107	0.0059	0.49
WS06	8.0	15	0.0030	0.0059	0.51
WS08	5.3	5	0.0809		
WS09	4.8	20	0.0001	0.0059	0.58
WS10	5.5	17	0.006	0.056	0.56
		pH			
WS01	7.5	13	0.7800		
WS02	7.5	14	0.8891		
WS03	7.7	20	0.3500		
WS04	7.4	13	0.9408		
WS06	7.2	16	0.5124		
WS08	7.7	6	0.0452	-0.0004	0.67
WS09	7.5	21	0.2563		
WS10	7.5	18	0.5387		
		SPC (umhos)			
WS01	1185	13	0.6227		
WS02	1110	14	0.7102		
WS03	1200	20	0.4410		
WS04	1084	13	0.8783		
WS06	1283	16	0.9628		
WS08	1351	6	0.3156		
WS09	1241	21	0.9294		
WS10	1184	18	0.9337		
		DOC (mg/l)			
WS01	6.06	9	0.6057		
WS02	4.9	7	0.1562		
WS03	6.9	15	0.1406		
WS04	3.88	6	0.1213		
WS06	2.07	9	0.1274		
WS08	0.46	5	0.0349	0.0006	0.82
WS09	3.71	14	0.3300		
WS10	3.34	11	0.4001		
		As (mg/l)			
WS01	0.017	17	0.0004	0.000008	0.58
WS02	0.016	18	0.0001	0.000008	0.77
WS03	0.016	25	0.0379	0.000006	0.17
WS04	0.029	16	0.1887		
WS06	0.018	19	0.0756		
WS08	0.018	9	0.1809		
WS09	0.024	23	0.1525		
WS10	0.015	21	0.0001	0.000009	0.77
		F (mg/l)			
WS01	0.3	17	0.1779		
WS02	0.3	16	0.8423		
WS03	0.3	25	0.6802		
WS04	0.3	17	0.6529		
WS06	0.6	20	0.0794		
WS08	0.6	10	0.2995		
WS09	0.5	25	0.4809		
WS10	0.5	2	0.5537		

TABLE 5.3.2-3

	Mean	Of Observations	$\hat{\alpha}$	Slope/Per Day	r^2
		B (mg/l)			
WS01	0.2	16	0.0296	-0.0003	0.2952
WS02	0.2	18	0.1810		
WS03	0.2	19	0.0244	-0.0002	0.2640
WS04	0.2	17	0.0296	-0.0002	0.2779
WS06	0.2	17	0.0123	-0.0003	0.3154
WS08	0.1	9	0.1516		
WS09	0.1	19	0.2106		
WS10	0.2	19	0.2065		
		TDS (mg/l)			
WS01	837	15	0.6126		
WS02	742	16	0.8676		
WS03	760	23	0.9015		
WS04	766	15	0.4917		
WS06	766	18	0.1132		
WS08	877	10	0.8672		
WS09	767	23	0.2925		
WS10	723	2	0.1777		
		Moly (mg/l)			
WS01	0.02	15	0.1314		
WS02	0.04	17	0.7137		
WS03	0.03	20	0.5242		
WS04	0.02	17	0.6511		
WS06	0.04	19	0.7651		
WS08	0.03	10	0.5016		
WS09	0.03	19	0.0113		
WS10	0.02	17	0.1621		
		Na (mg/l)			
WS01	131	17	0.1180		
WS02	112	18	0.6791		
WS03	132	24	0.0185	-0.0113	0.22
WS04	112	17	0.1925		
WS06	136	20	0.3977		
WS08	124	10	0.8615		
WS09	121	25	0.9185		
WS10	114		0.3098		
		SO_4 (mg/l)			
WS01	361	17	0.0902		
WS02	309	18	0.0228	0.0330	0.28
WS03	405	25	0.9165		
WS04	318	17	0.9384		
WS06	356	20	0.9117		
WS08	340	10	0.7988		
WS09	330	25	0.8720		
WS10	335	20	0.9658		
		NH_3 (mg/l)			
WS01	0.13	14	0.3461		
WS02	0.18	17	0.4462		
WS03	0.13	24	0.4537		
WS04	0.17	15	0.1677		
WS06	0.08	15	0.0025	-0.0001	0.52
WS08	0.14	19	0.4973		
WS09	0.09	23	0.5200		
WS10	0.11	20	0.4768		

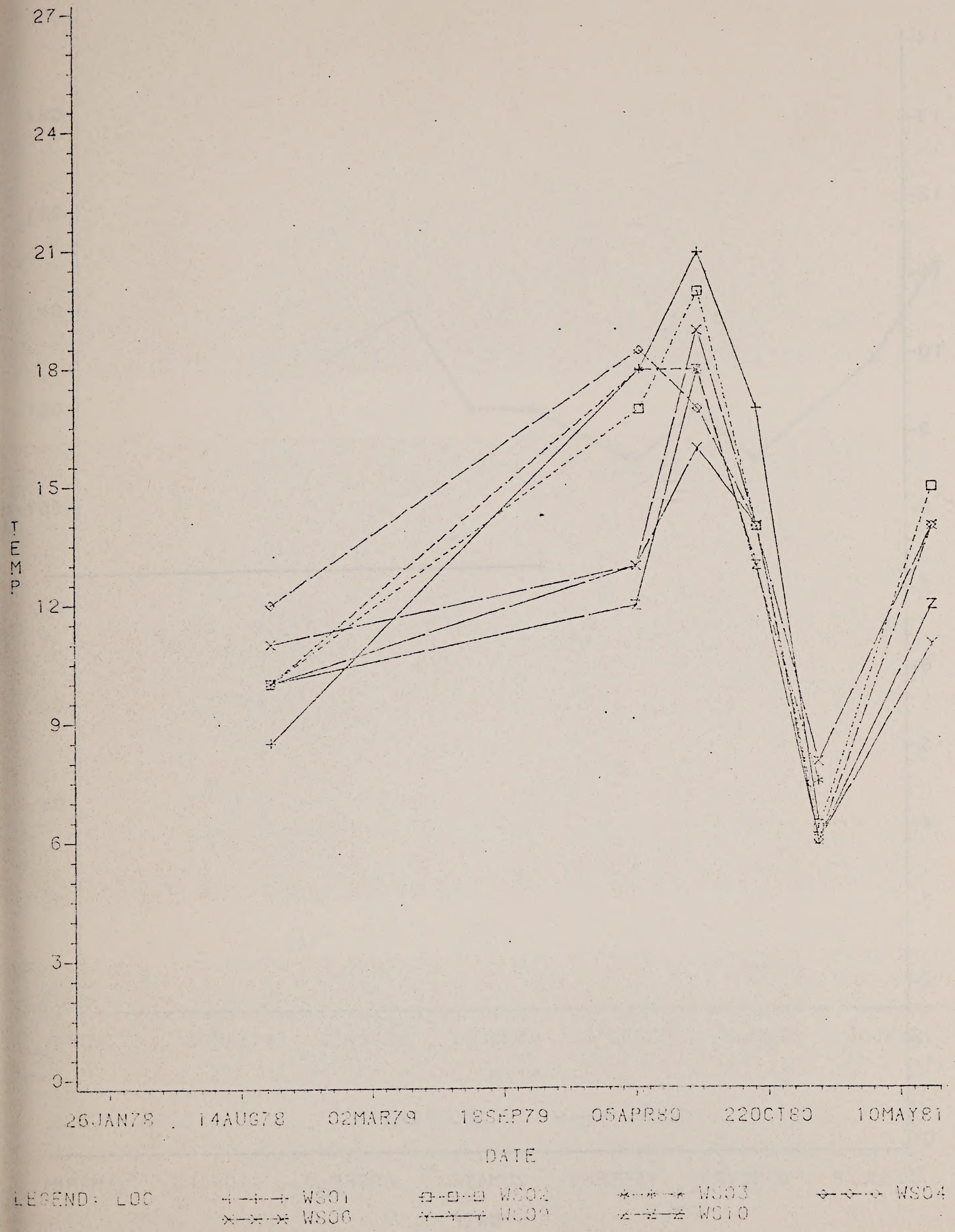


FIGURE 5.3.2-1

TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: TEMPERATURE

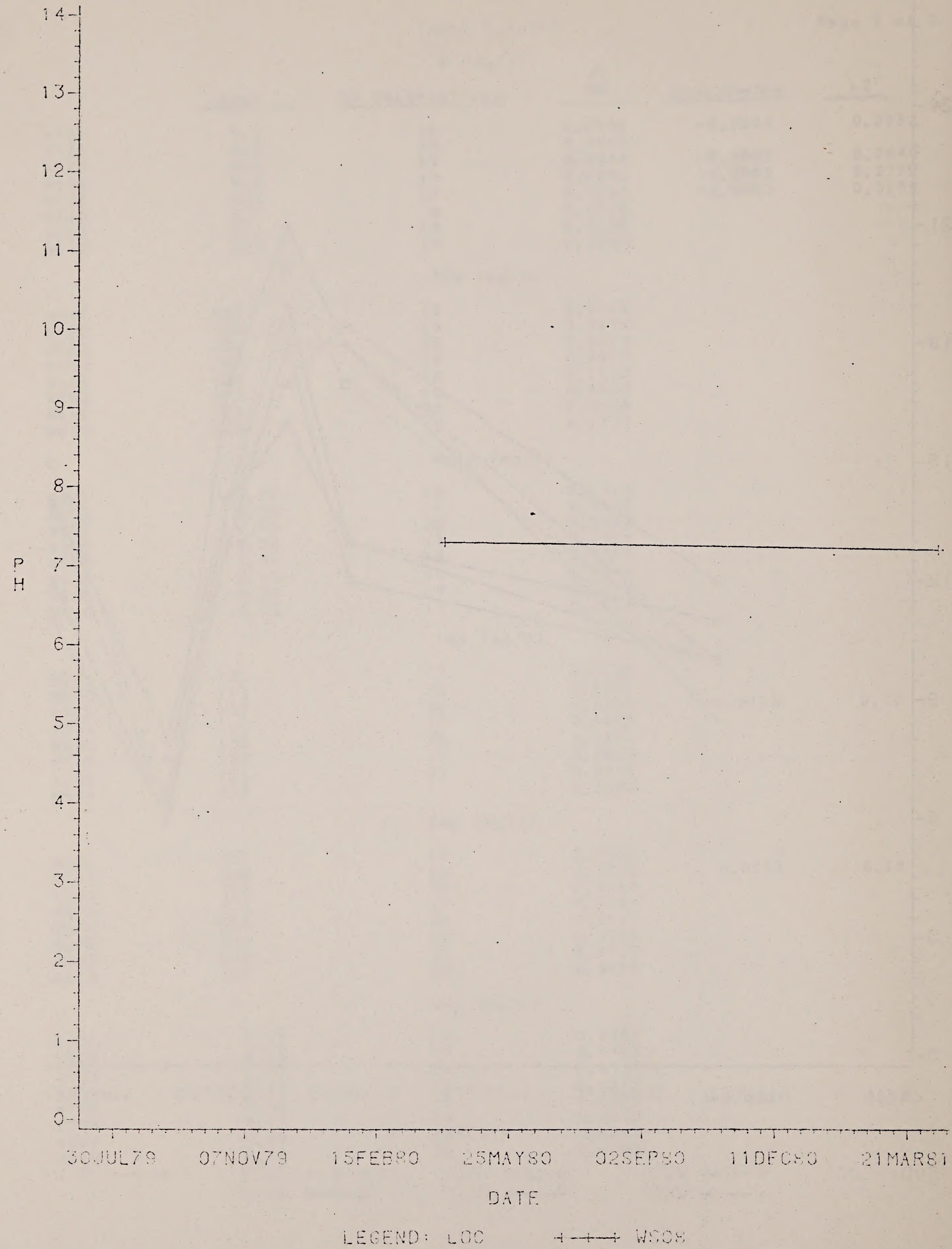


FIGURE 5.3.2-2

TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: pH

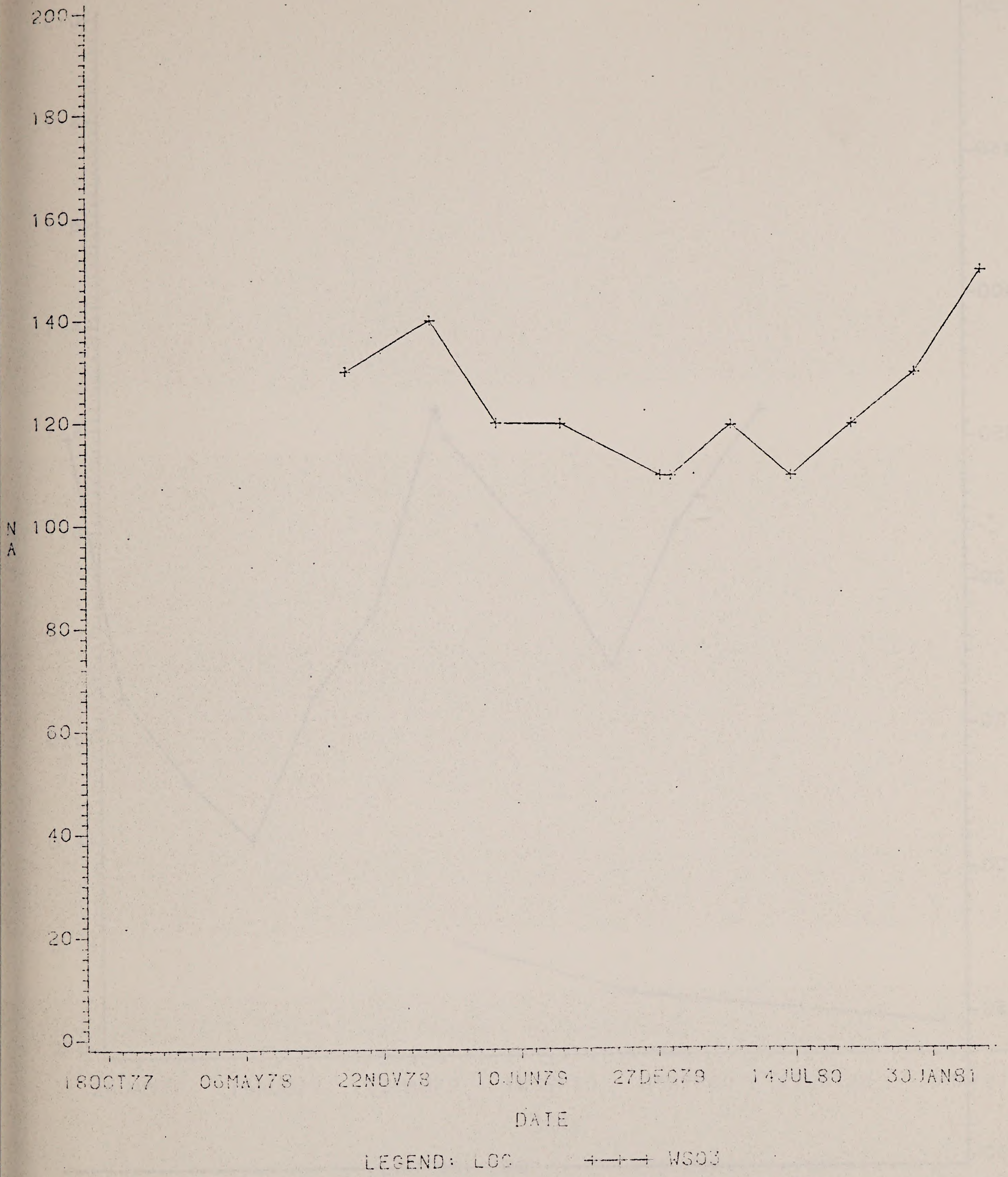


FIGURE 5.3.2-3
TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: SODIUM

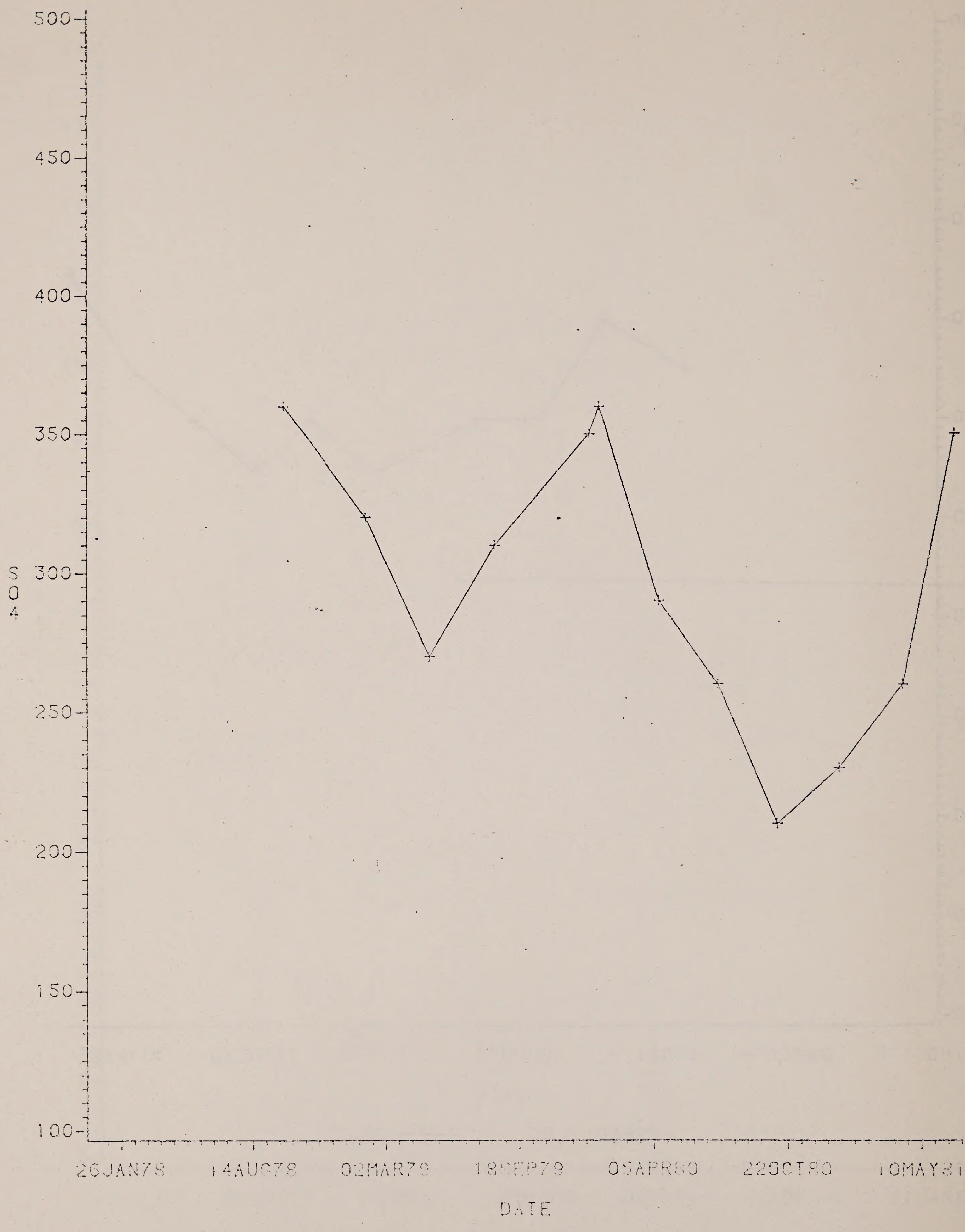


FIGURE 5.3.2-4
TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: SULFATE

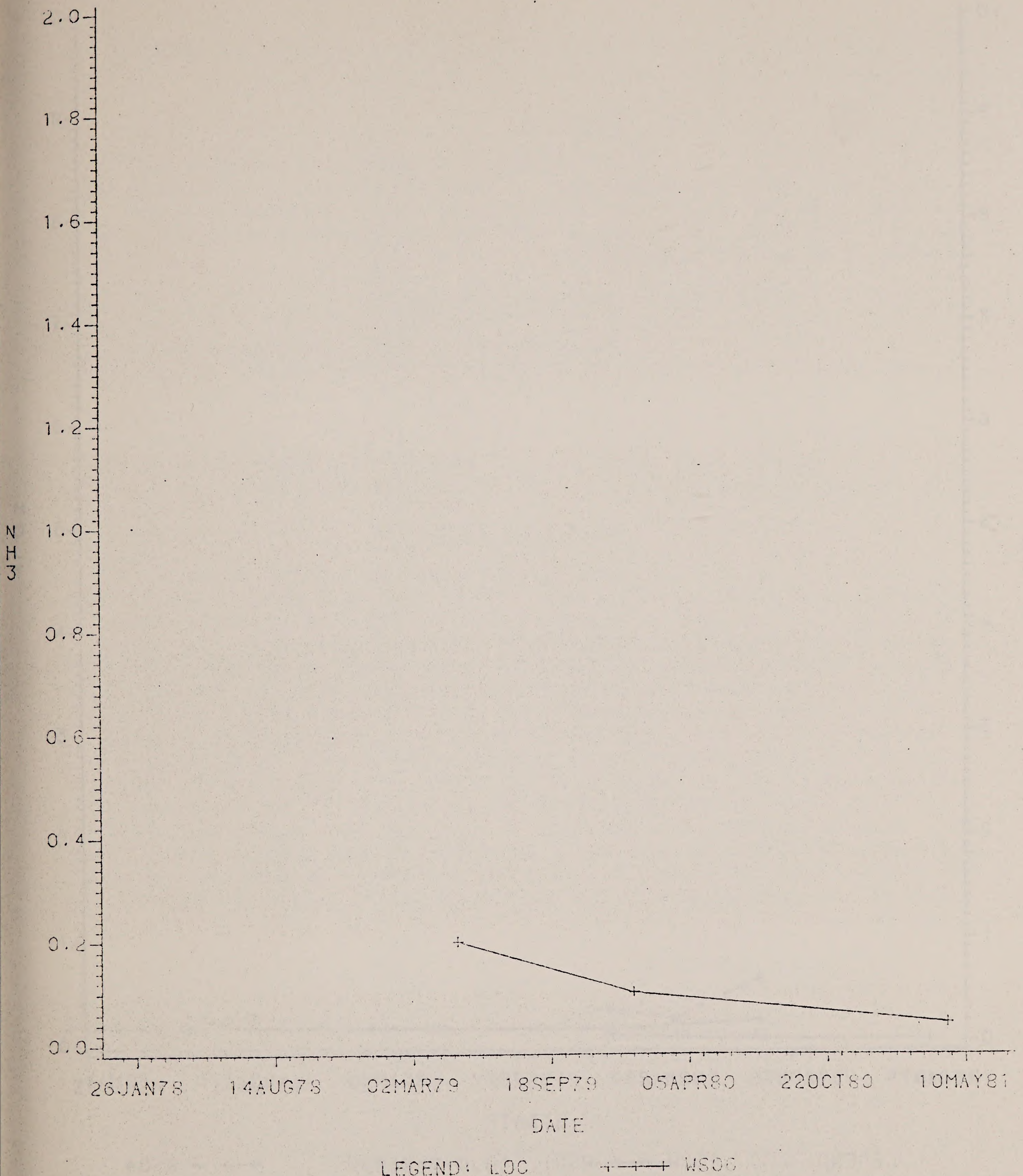


FIGURE 5.3.2-5

TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: AMMONIA

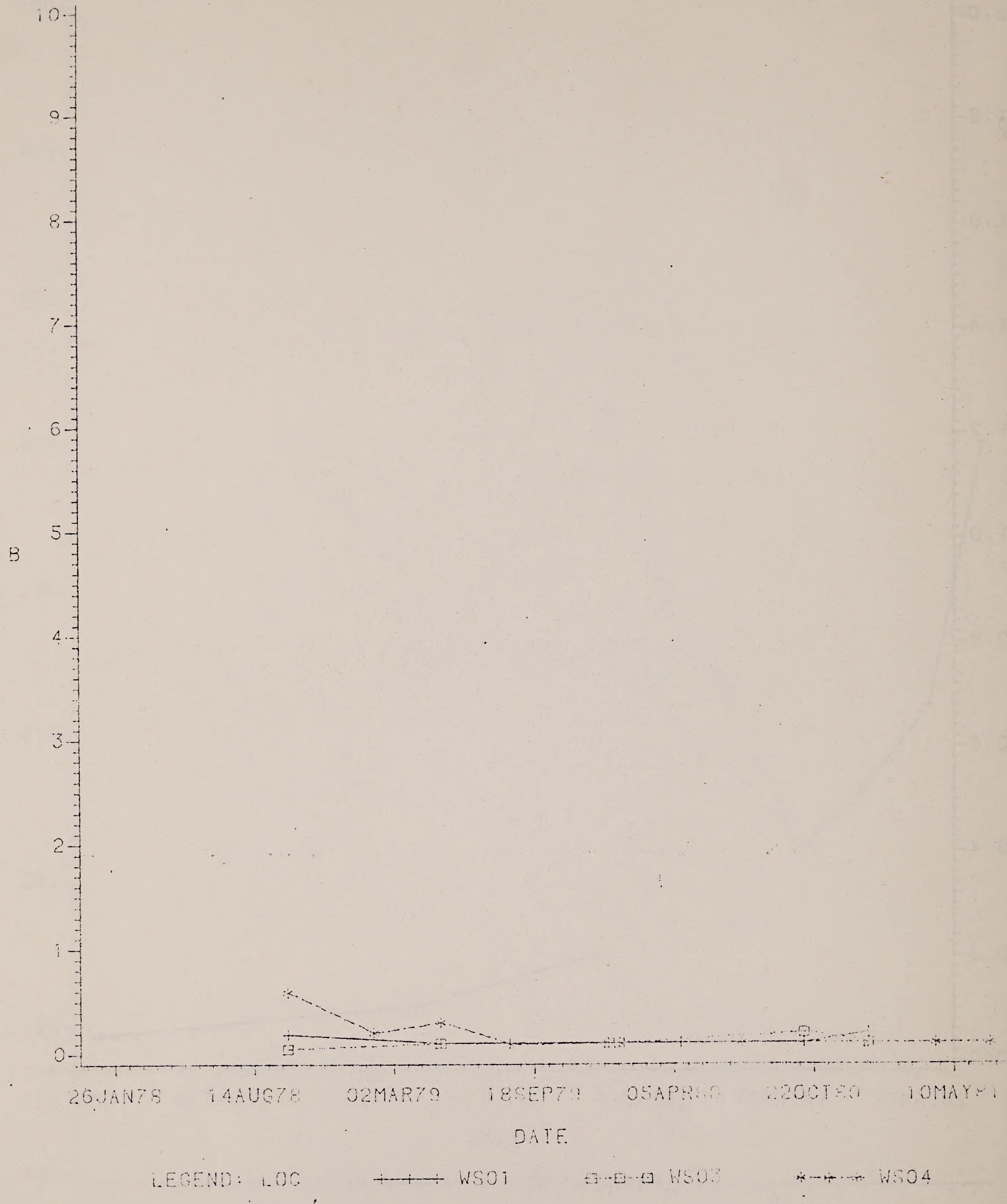


FIGURE 5.3.2-6

TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: BORON

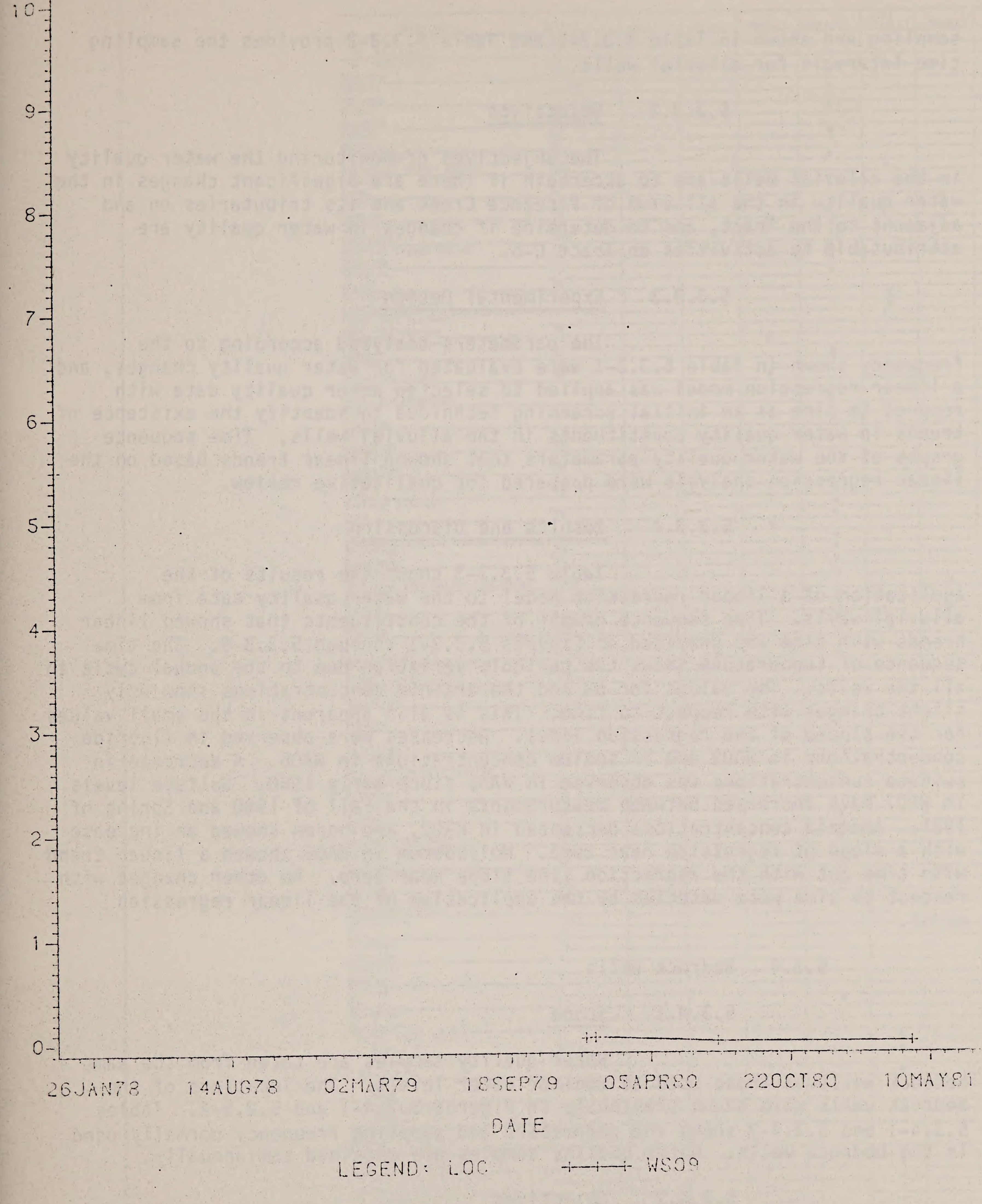


FIGURE 5.3.2-7

TIME SERIES OF WATER QUALITY PARAMETERS FOR SPRINGS: MOLYBDENUM

sampling are shown in Table 5.3.3-1 and Table 5.3.3-2 provides the sampling time intervals for alluvial wells.

5.3.3.2 Objectives

The objectives of monitoring the water quality in the alluvial wells are to ascertain if there are significant changes in the water quality in the alluvium of Piceance Creek and its tributaries on and adjacent to the Tract, and to determine if changes in water quality are attributable to activities on Tract C-b.

5.3.3.3 Experimental Design

The parameters analyzed according to the frequency shown in Table 5.3.3-1 were evaluated for water quality changes, and a linear regression model was applied to selected water quality data with respect to time as an initial screening technique to identify the existence of trends in water quality constituents in the alluvial wells. Time sequence graphs of the water quality parameters that showed linear trends based on the linear regression analysis were prepared for qualitative review.

5.3.3.4 Results and Discussion

Table 5.3.3-3 shows the results of the application of a linear regression model to the water quality data from alluvial wells. Time sequence graphs of the constituents that showed linear trends with time are provided as Figures 5.3.3-1 through 5.3.3-9. The time sequence of temperature shows the periodic variation due to the annual cycle in all the wells. The values for pH and the arsenic concentrations show only slight changes with respect to time. This is also apparent in the small values for the slopes of the regression lines. Decreases were observed in fluoride concentrations in WA02 and in sodium concentrations in WA06. A decrease in sulfate concentrations was observed in WA06 since early 1980. Sulfate levels in WA07 have increased between measurements in the Fall of 1980 and Spring of 1981. Ammonia concentrations decreased in WA02, and boron showed an increase with a slope of regression near zero. Molybdenum in WA06 showed a linear trend with time but with the regression line slope near zero. No other changes with respect to time were detected by the application of the linear regression model.

5.3.4 Bedrock Wells

5.3.4.1 Scope

Water quality samples are taken from the same bedrock wells as those used to monitor water levels. The locations of the bedrock wells were shown previously in Figures 5.2.4-1 and 5.2.5-2. Tables 5.3.4-1 and 5.3.4-2 shows the parameters and sampling frequency normally used in the bedrock wells. Water quality samples are obtained semiannually.

5.3.4.2 Objectives

The objectives of measuring the water quality in the bedrock wells are to monitor the constituents or parameters for long-term

TABLE 5.3.3-1

WATER SAMPLING FREQUENCY REQUIREMENTS

ALLUVIAL WELLS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$				●		
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_3				●		
Antimony							
Arsenic	As				●		
Bacteria	Sb						
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3				●		
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B				●		
Bromine	Br						●
Cadmium	Cd				●		
Calcium	Ca				●		
Carbonate	CO_3				●		
Chemical Oxygen Oemand	COD				●		
Chloride	Cl				●		
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal						●	
Coliform, Total						●	
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC			●			
Copper	Cu				●		
Cyanide	Cn						
Dissolved Oxygen	DO			●			
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F				●		
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)					●		
Hydroxides	OH						
Iooine	I						
Iron	Fe				●		
Kjeldahl Nitrogen					●		
Lead	Pb				●		
Level				●			
Lithium	Li				●		
Magnesium	Mg				●		
Manganese	Mn				●		
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS						●
Molybdenum	Mo				●		
Nickel	Ni				●		
Nitrate	NO_3				●		
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH			●			
Phenols					●		
PNA	PNA						
Potassium	K				●		
Rubidium	Rb						
Sediment Characterization							
Selenium	Se				●		
Scandium	Sc						
Silica	SiO_2						
Silver	Ag				●		
Sodium	Na				●		
Solids, Dissolved	TDS				●		
Solids, Suspended	TSS						
Strontium	Sr				●		
Surfactants							
Sulfate	SO_4				●		
Sulfide	SO_2						
Temperature (°C)				●			
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vandium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Ce137						
Sr90							
Thorium 230	Th230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* Stations WA01, WA02, WA03, WA04, WA05, WA06, WA07, WA08, WA09, WA10, WA11, WA12, WA13, WA55.

Current status of wells (Dec., 1981) WA02 and WA07 are plugged. WA04 and WA13 are dry. All others are being sampled.

SYMBOLS:

● Applies to all stations.

TABLE 5.3.3-2

ALLUVIAL WELLS
SAMPLING TIME INTERVALS
FOR QUALITY

COMPUTER CODE	1974	1975	1976	1977	1978	1979	1980	1981
WA01	1	2	8	1	2	2	3	3
WA02	1	2	2			1	3	3
WA03	1	1	8		1	2	3	2
WA05	1	2	2		1		3	2
WA06	1	1	8		1	2	3	2
WA07	1	2	8		1	1	1	2
WA08	1	2	2		3		2	2
WA09	1	2	2		3	1	3	3
WA10	1	2	2		3			
WA11	1	2	2		3	1		
WA12	1	2	2		3	1	2	3
WA56							1	2

TABLE 5.3.3-3

Long-Term Time Series Analysis of Alluvial Wells

	Mean	Of Observations	$\hat{\alpha}$	Slope/Per Day	r^2
		Temperature °C			
WS01	5.9	20	0.0001	0.0074	0.65
WS02	5.7	10	0.0003	0.0054	0.82
WS03	3.9	16	0.0001	0.0063	0.77
WS05	6.9	10	0.0163	0.0058	0.53
WS06	4.6	16	0.0009	0.0066	0.56
WS07	3.3	14	0.0036	0.0070	0.52
WS08	7.1	12	0.0618	-	-
WS09	7.8	13	0.0101	0.0067	0.47
WA10	5.9	8	0.0157	0.0131	0.65
WA11	4.9	9	0.1511	-	-
WA12	7.3	14	0.6350	-	-
		pH			
WS01	7.5	20	0.2030	-	-
WS02	7.8	10	0.0499	-0.0003	0.40
WS03	7.4	16	0.1973	-	-
WS05	7.9	10	0.0403	-0.0003	0.43
WS06	7.5	16	0.2377	-	-
WS07	8.2	15	0.0151	-0.0002	0.38
WS08	7.9	12	0.0368	-0.0003	0.37
WS09	7.4	14	0.6138	-	-
WS10	8.0	8	0.0135	-0.00049	0.67
WS11	7.1	9	0.1280	-	-
WS12	8.1	13	0.0199	0.0060	0.40
		SPC (umhos)			
WS01	1493	20	0.3622	-	-
WS02	1137	10	0.7450	-	-
WS03	1253	16	0.1781	-	-
WS05	1288	10	0.1536	-	-
WS06	1314	16	0.0672	-	-
WS07	1169	15	0.5702	-	-
WS08	1103	12	0.5146	-	-
WS09	920	14	0.8037	-	-
WS10	1150	8	0.3854	-	-
WS11	1085	9	0.0689	-	-
WS12	1206	14	0.6694	-	-
		DOC (mg/l)			
WS01	3.47	17	0.8996	-	-
WS02	1.60	8	0.2880	-	-
WS03	2.12	13	0.5693	-	-
WS05	2.02	8	0.6956	-	-
WS06	2.73	13	0.5929	-	-
WS07	2.85	13	0.5515	-	-
WS08	4.26	10	0.7854	-	-
WS09	3.70	11	0.6133	-	-
WS10	7.07	8	0.1057	-	-
WS11	6.57	8	0.1620	-	-
WS12	5.42	11	0.6585	-	-
		As (mg/l)			
WS01	0.012	20	0.0001	0.000009	0.72
WS02	0.015	11	0.0209	0.00006	0.46
WS03	0.014	16	0.1093	-	-
WS05	0.017	17	0.7199	-	-
WS06	0.013	17	0.0722	-	-
WS07	0.012	15	0.2400	-	-
WS08	0.013	12	0.0006	0.00001	0.71
WS09	0.015	15	0.0001	-	0.71
WS10	0.009	8	0.0052	-	0.75
WS11	0.011	9	0.0057	-	0.69
WS12	0.015	14	0.0005	0.00001	0.65

TABLE 5.3.3-3

	Mean	Of Observations	$\hat{\alpha}$	Slope/Per Day	r^2
		F (mg/l)			
WS01	0.949	22	0.2996	-	-
WS02	1.642	12	0.0131	-0.0008	0.48
WS03	0.476	18	0.2607	-	-
WS05	0.973	11	0.2075	-	-
WS06	0.521	18	0.3395	-	-
WS07	0.289	16	0.2576	-	-
WS08	0.283	12	0.5039	-	-
WS09	0.247	15	0.0614	-	-
WA10	0.338	8	0.2820	-	-
WA11	0.234	9	0.01566	-	-
WA12	0.337	14	0.0560	-	-
		SO_4 (mg/l)			
WS01	405	22	0.6720	-	-
WS02	275	12	0.4880	-	-
WS03	353	18	0.3581	-	-
WS05	305	11	0.2081	-	-
WS06	309	18	0.0001	-0.0545	0.65
WS07	280	16	0.0188	-0.0499	0.33
WS08	378	12	0.2004	-	-
WS09	311	15	0.5512	-	-
WS10	399	8	0.0093	-0.0620	0.70
WS11	428	9	0.1621	-	-
WS12	461	14	0.7388	-	-
		B (mg/l)			
WS01	0.229	17	0.8917	-	-
WS02	0.280	10	0.0857	-	-
WS03	0.137	13	0.1191	-	-
WS05	0.203	10	0.0595	-	-
WS06	0.272	13	0.0879	-	-
WS07	0.292	11	0.1212	-	-
WS08	0.143	11	0.1304	-	-
WS09	0.253	14	0.1536	-	-
WS10	0.307	6	0.0778	-	-
WS11	0.281	8	0.1252	-	-
WS12	0.562	13	0.0779	-	-
		Moly (mg/l)			
WS01	0.027	17	0.1471	-	-
WS02	0.015	10	0.1851	-	-
WS03	0.015	12	0.1236	-	-
WS05	0.022	10	0.0722	-	-
WS06	0.023	12	0.0001	-0.000016	0.50
WS07	0.031	10	0.0949	-	-
WS08	0.024	10	0.3597	-	-
WS09	0.021	14	0.0433	-0.000013	0.30
WS10	0.017	6	0.1138	-	-
WS11	0.037	6	0.5750	-	-
WS12	0.023	12	0.0196	-0.00001	0.44
		NH_3 (mg/l)			
WS01	1.26	19	0.4424	-	-
WS02	0.344	12	0.0099	-0.0002	0.50
WS03	0.091	14	0.3301	-	-
WS05	0.150	8	0.0492	-0.0002	0.50
WS06	0.101	16	0.4348	-	-
WS07	0.451	14	0.3420	-	-
WS08	0.736	10	0.5086	-	-
WS09	0.319	13	0.0820	-	-
WS10	0.408	5	0.5356	-	-
WS11	0.928	6	0.4566	-	-
WS12	0.162	11	0.0609	-	-

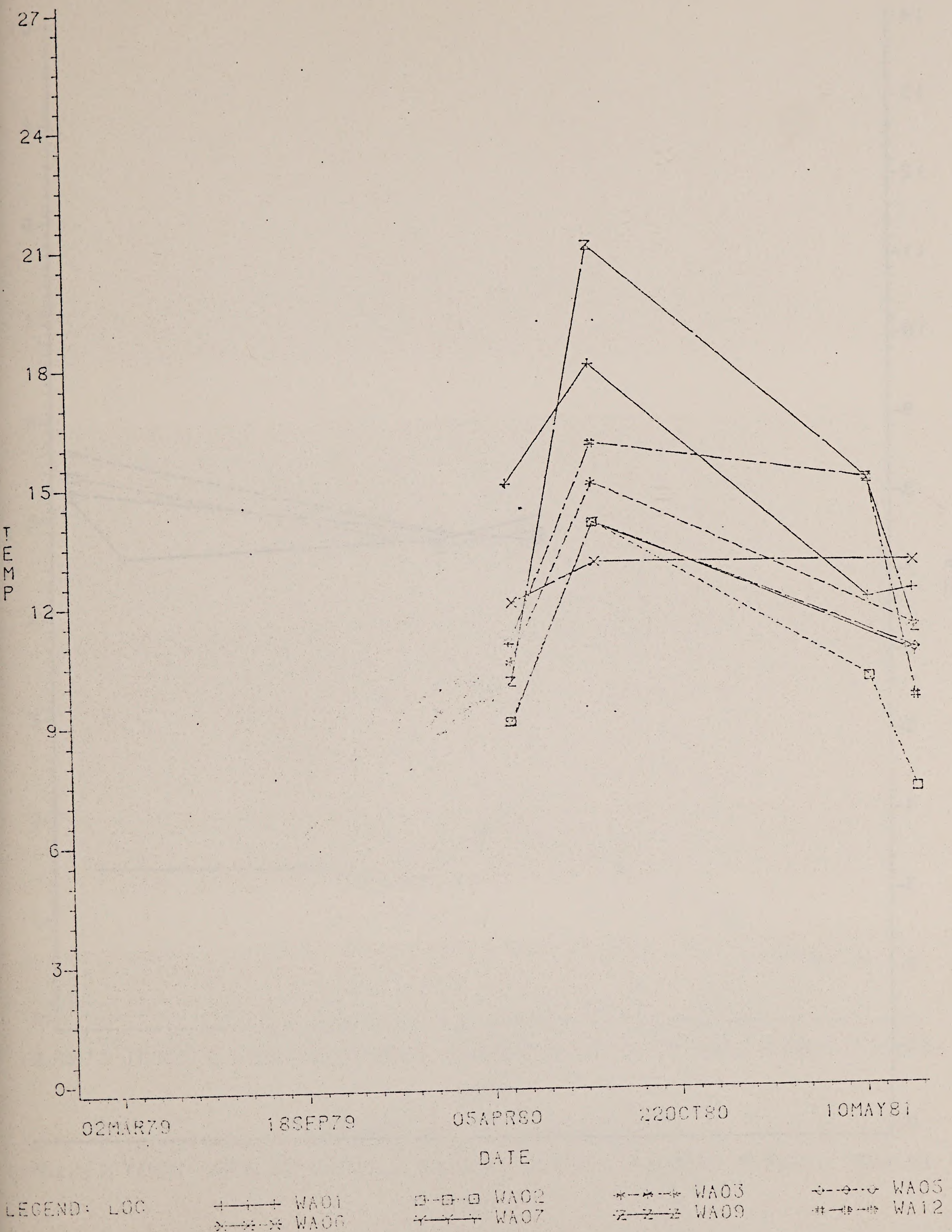


FIGURE 5.3.3-1

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: TEMPERATURE

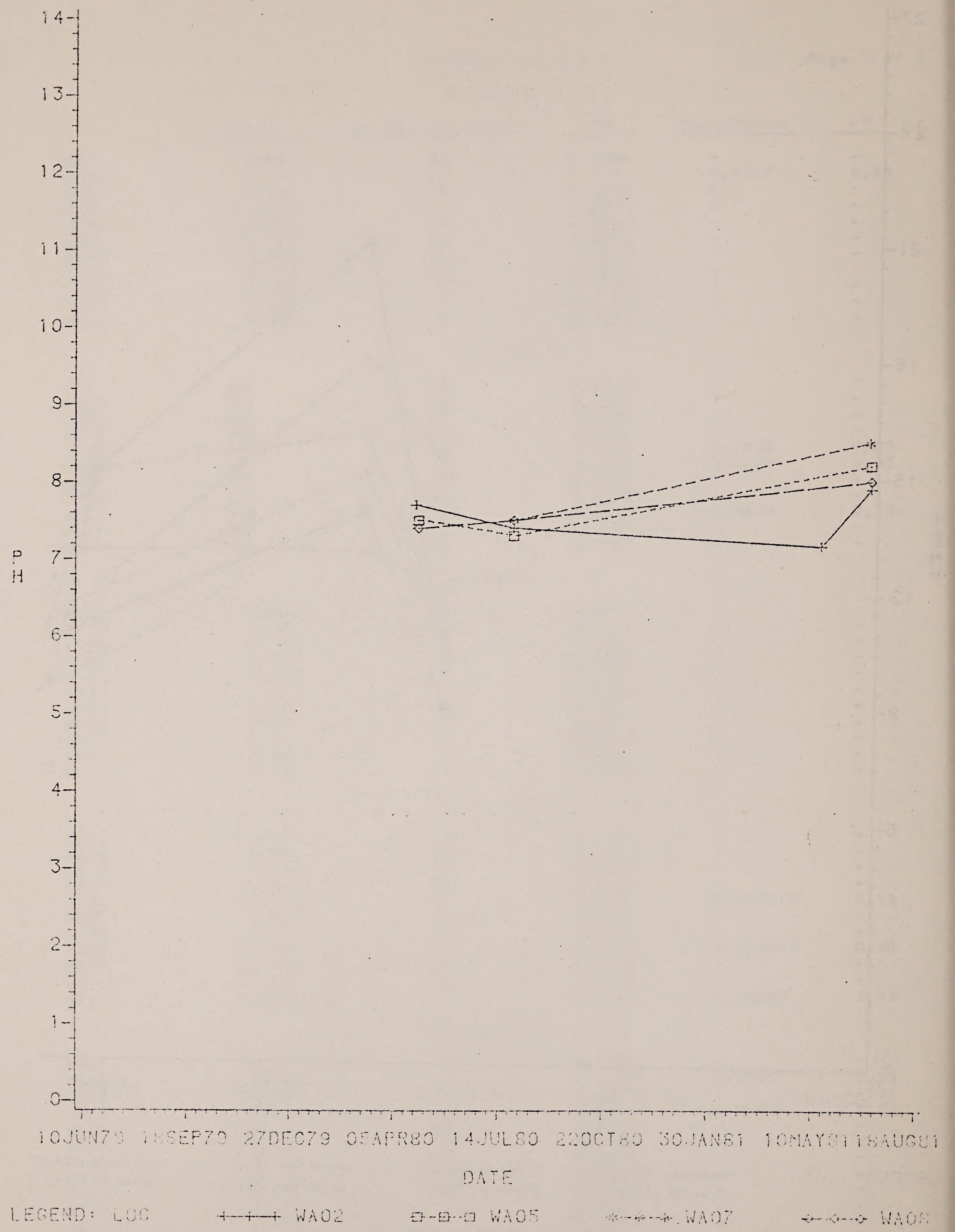


FIGURE 5.3.3-2

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: pH

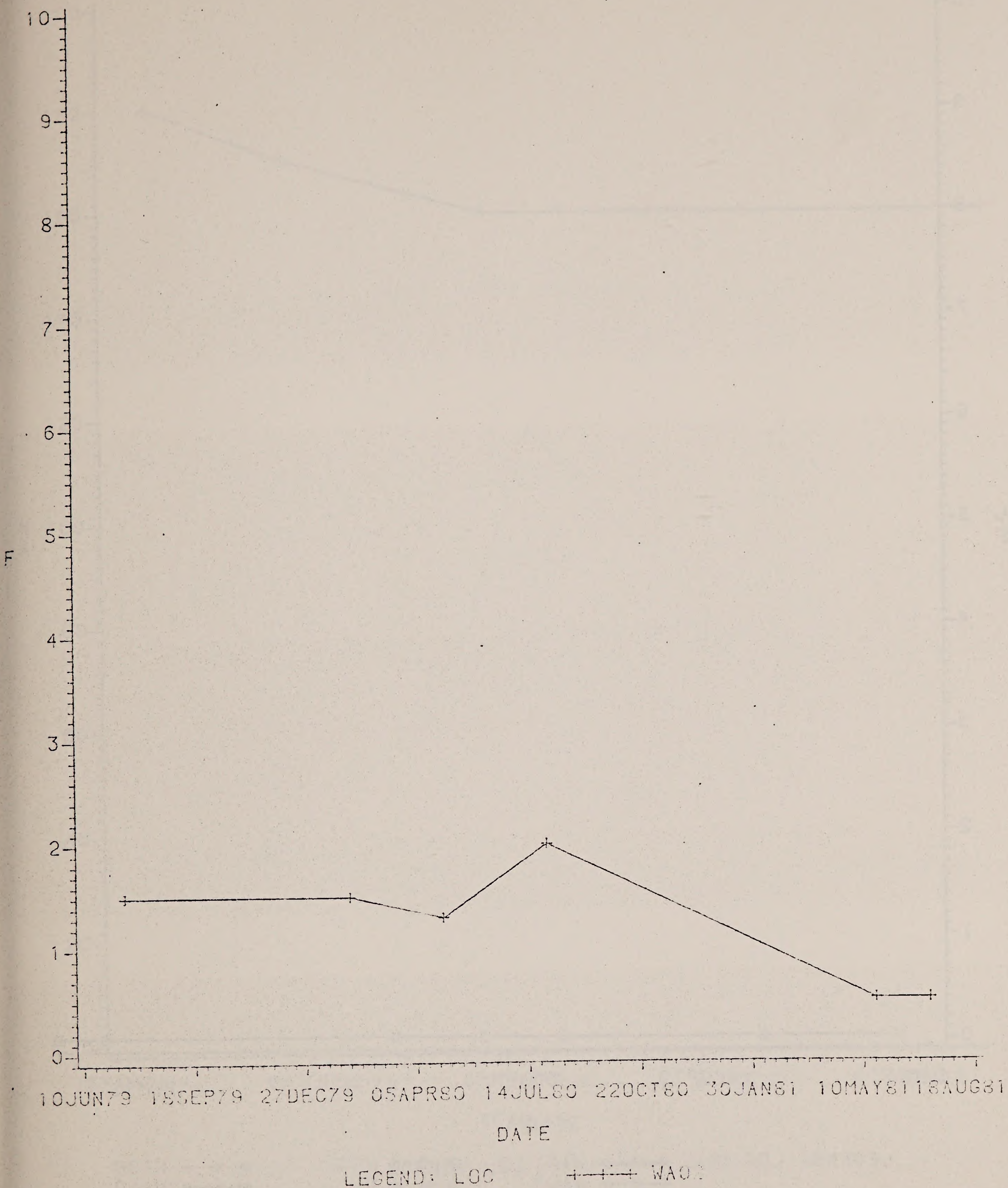


FIGURE 5.3.3-3

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: FLUORIDE

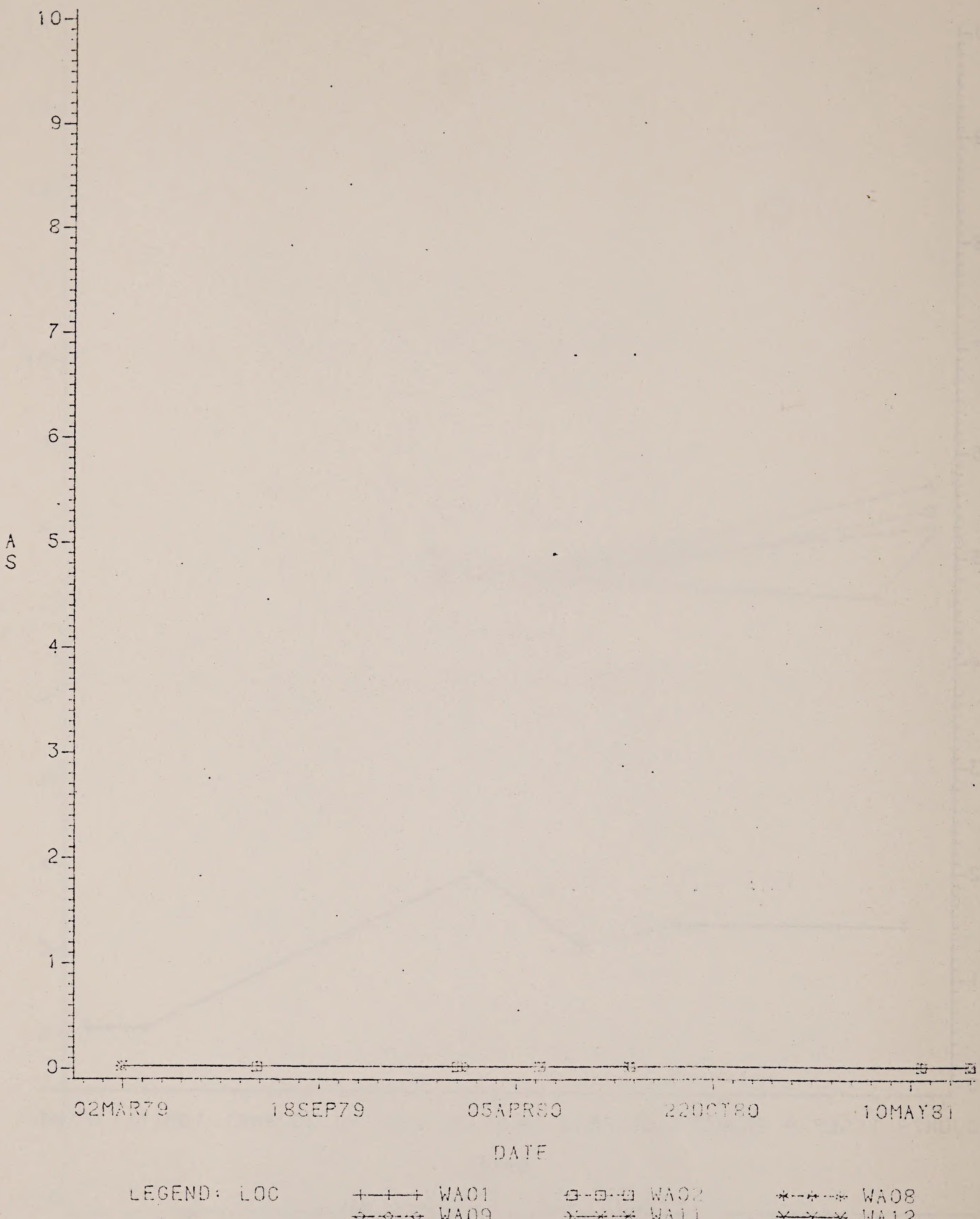


FIGURE 5.3.3-4

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: ARSENIC

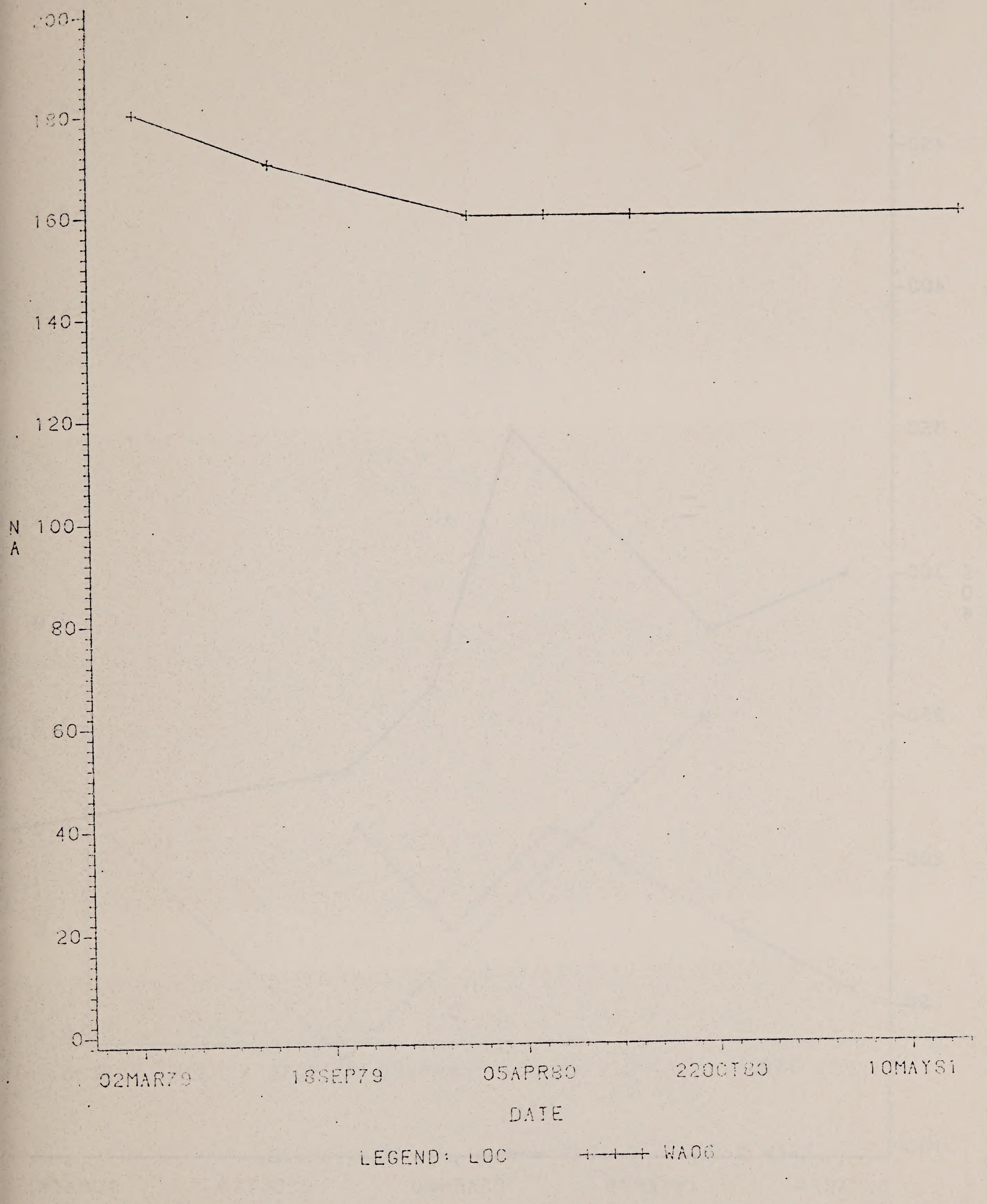


FIGURE 5.3.3-5

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: SODIUM

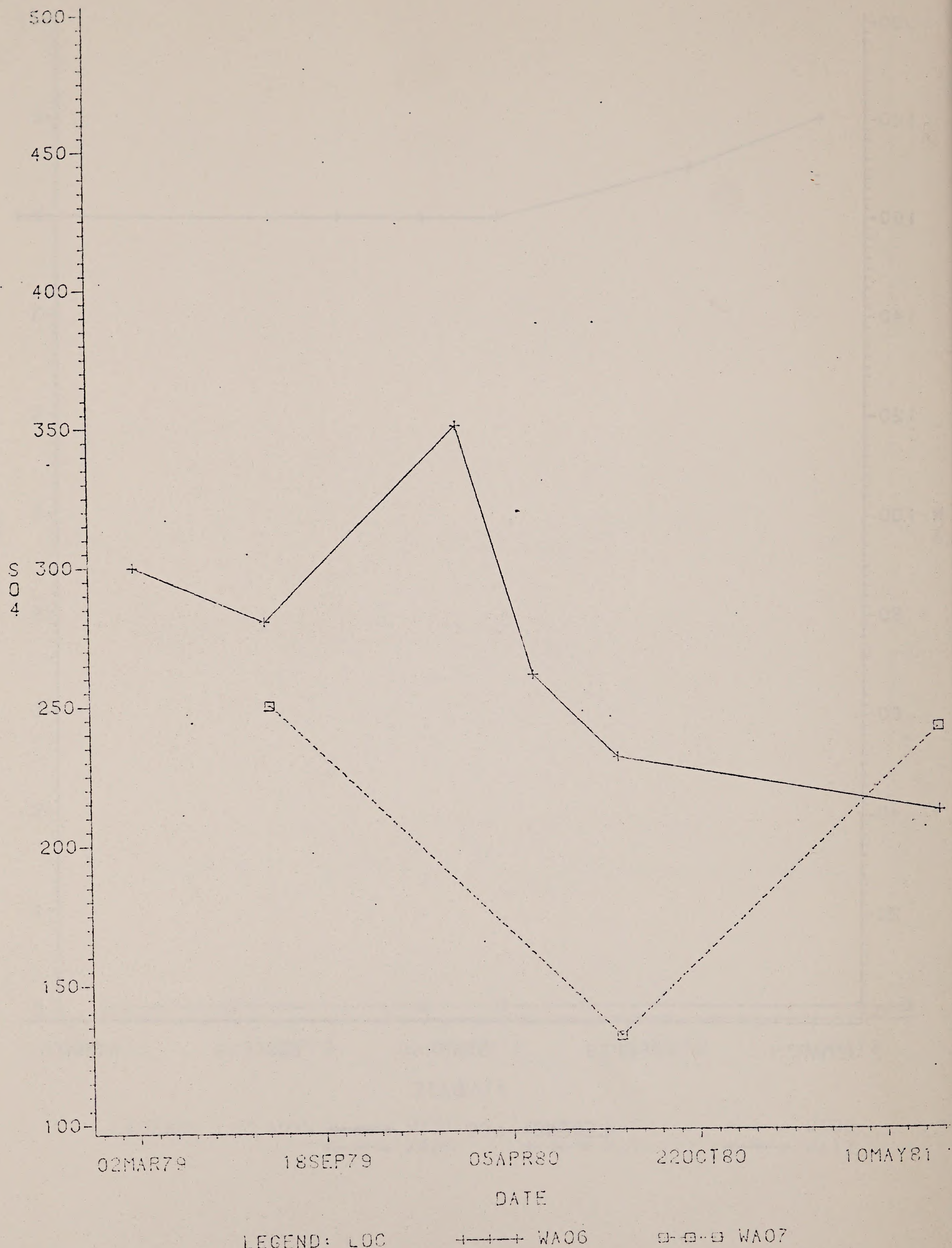


FIGURE 5.3.3-6

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: SULFATE

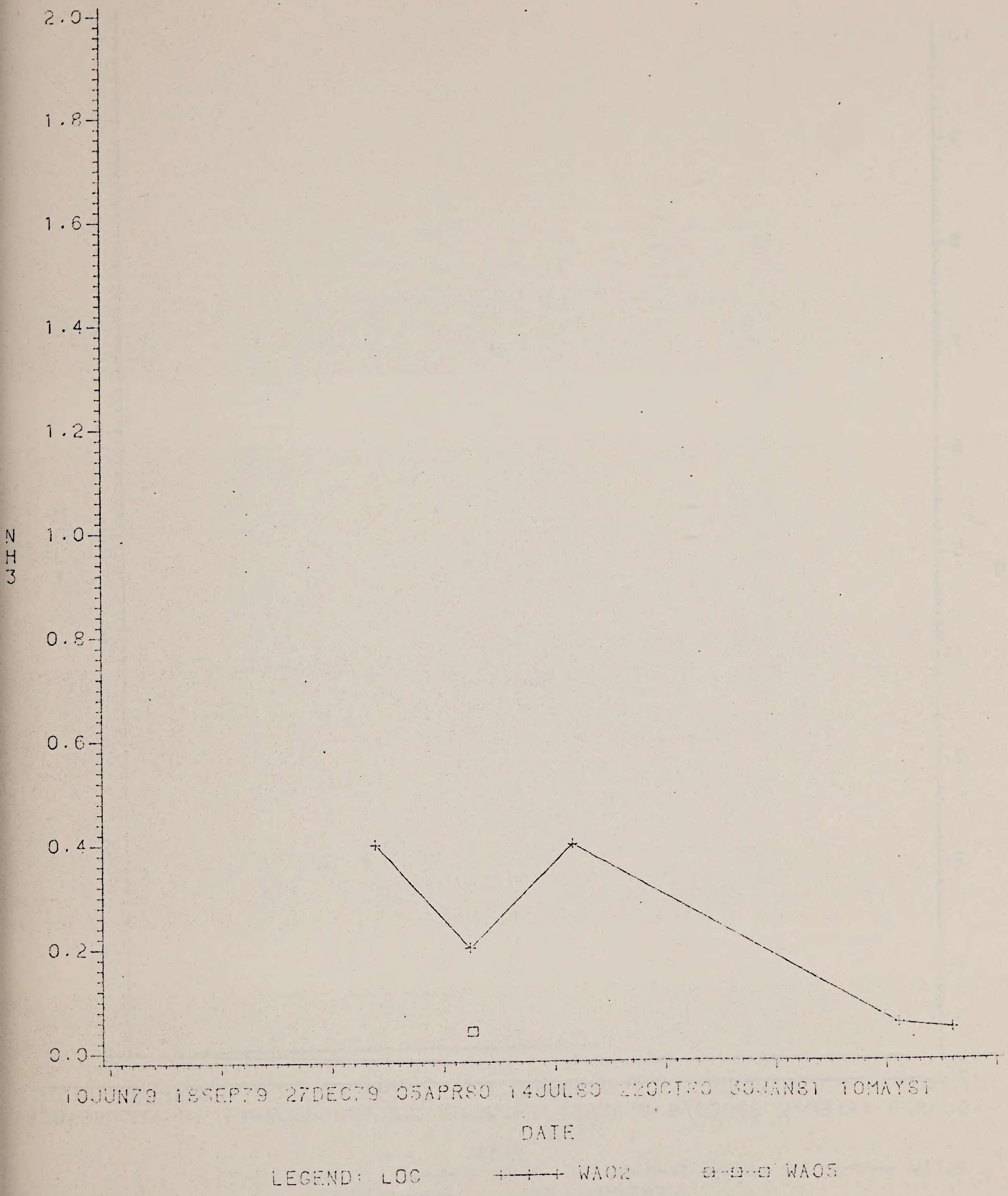


FIGURE 5.3.3-7

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: AMMONIA

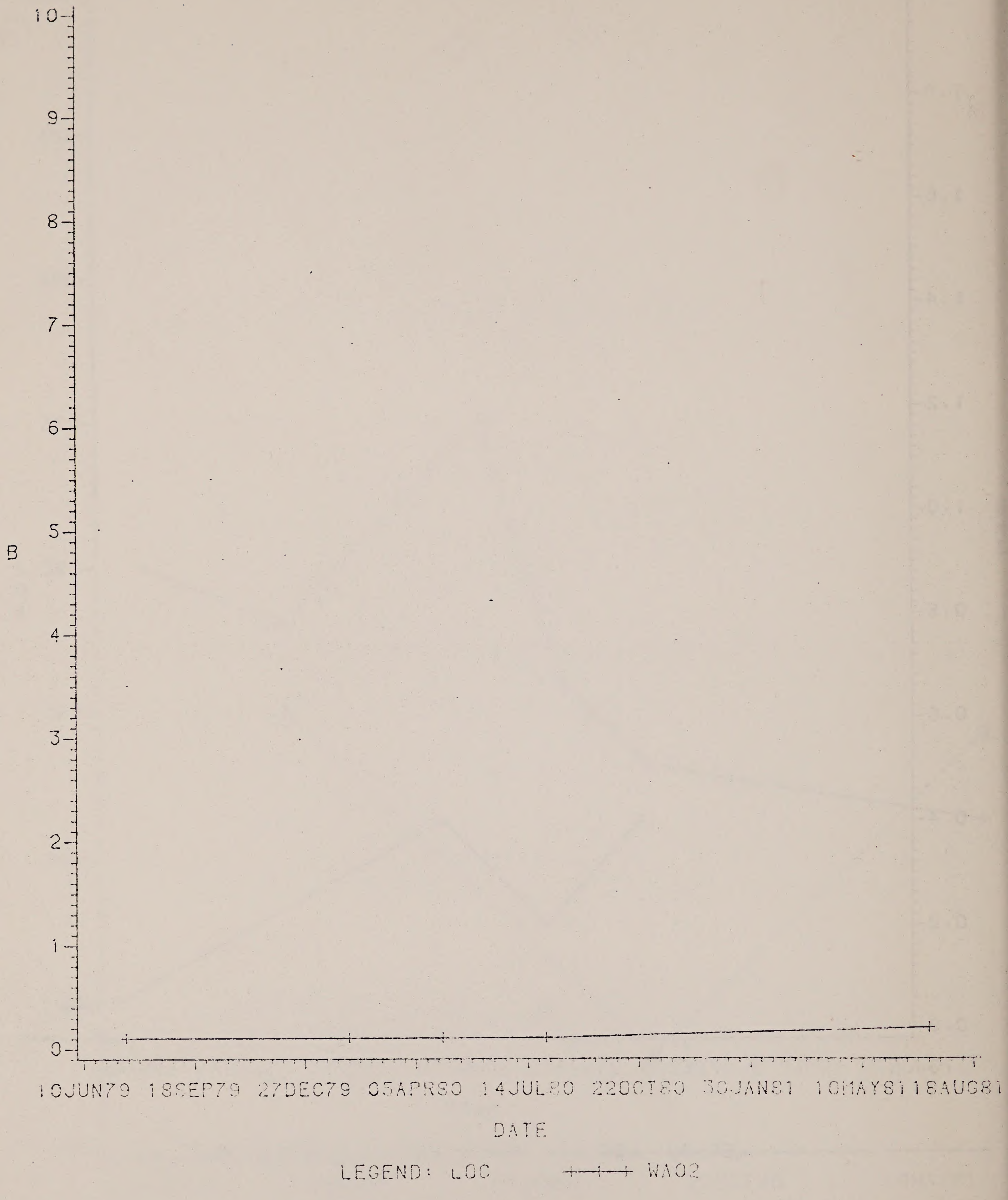


FIGURE 5.3.3-8

TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: BORON

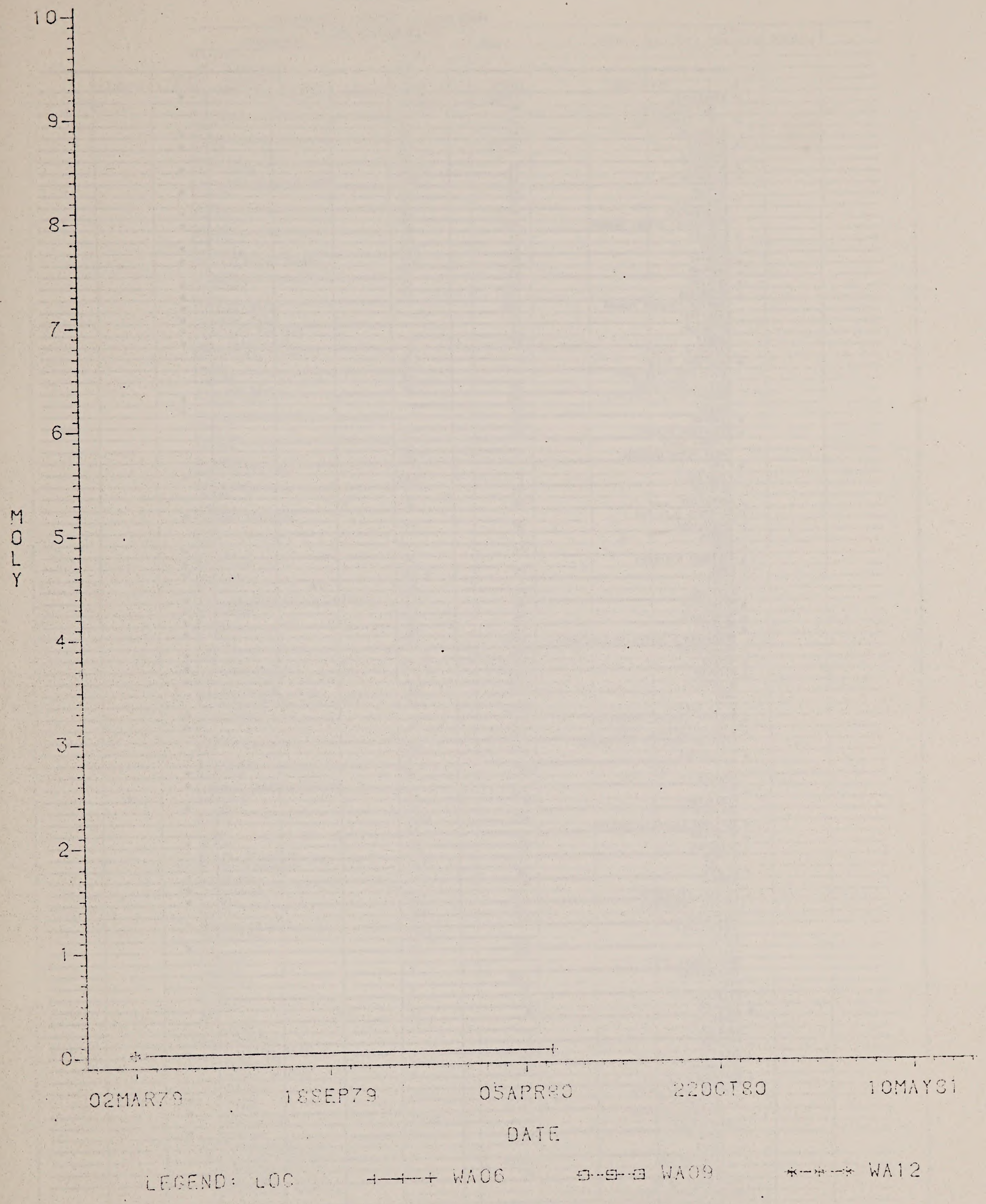


FIGURE 5.3.3-9
TIME SERIES OF WATER QUALITY PARAMETERS FOR ALLUVIAL WELLS: MOLYBDENUM

TABLE 5.3.4-1

WATER SAMPLING FREQUENCY REQUIREMENTS
UPPER AQUIFER WELLS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al					●	
Ammonia	as NH_3					●	
Antimony							
Arsenic	As					●	
Bacteria	Sb						
Barium	Ba					●	
Beryllium	Be						
Bicarbonate	HCO_3					●	
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B					●	
Bromine	Br					●	
Cadmium	Cd						
Calcium	Ca					●	
Carbonate	CO_3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl					●	
Chromium	Cr					●	
Cobalt	Co					●	
Coliform, Fecal							
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC					●	
Copper	Cu					●	
Cyanide	Cn						
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F					●	
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)						●	
Hydroxides	OH						
Iodine	I						
Iron	Fe					●	
Kjeldahl Nitrogen						●	
Lead	Pb					●	
Level				■			
Lithium	Li					●	
Magnesium	Mg					●	
Manganese	Mn					●	
Mercury	Hg					●	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					●	
Nickel	Ni					●	
Nitrate	NO_3					●	
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR					●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH					●	
Phenols						●	
PNA	PNA						▲
Potassium	K					●	
Rubidium	Rb						
Sediment Characterization							
Selenium	Se					●	
Scandium	Sc						
Silica	SiO_2						
Silver	Ag					●	
Sodium	Na					●	
Solids, Dissolved	TDS					●	
Solids, Suspended	TSS						
Strontium	Sr					●	
Surfactants							
Sulfate	SO_4					●	
Sulfide	SO_2						
Temperature (°C)							
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vandium	V						
Yttrium	Y						
Zinc	Zn					●	
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Ce137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a.Hydrophobic Bases							
b.Hydrophobic Acids							
c.Hydrophobic Neutrals							
d.Hydrophilic Bases							
e.Hydrophilic Acids							
f.Hydrophilic Neutrals							

*Group 1: WX02; WX04, WX10, WX12, WX17, WX18, WX19, WX20, WX21, WX32, WX33, WX44, WX55, WX63, WX92

Group 2: WX64 thru WX67, WX69, WX71 thru WX73

SYMBOLS:

- ● Applies to Group 1 stations.
- ▲ Applies to stations and species to be identified.
- ■ Applies to all stations.

TABLE 5.3.4-2

WATER SAMPLING FREQUENCY REQUIREMENTS
LOWER AQUIFER WELLS *

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$					●		
MO Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al					●		
Ammonia	as NH_3					●		
Antimony								
Arsenic	As					●		
Bacteria	Sb							
Barium	Ba					●		
Beryllium	Be							
Bicarbonate	HCO_3					●		
Biological Oxygen Demand	BOD					●		
Bismuth	Bi							
Boron	B					●		
Bromine	Br							
Cadmium	Cd							
Calcium	Ca					●		
Carbonate	CO_3					●		
Chemical Oxygen Demand	COD					●		
Chloride	Cl					●		
Chromium	Cr					●		
Cobalt	Co					●		
Coliform, Fecal								
Coliform, Total								
Color (Not Precise)								
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC							
Copper	Cu					●		
Cyanide	Cn							
Dissolved Oxygen	DO							
Element Scan								
Fecal Streptococcus								
Flow						●		
Fluoride	F					●		
Gallium	Ga							
Germanium	Ge							
Hardness (Ca, Mg)						●		
Hydroxides	OH							
Iodine	I							
Iron	Fe					●		
Kjeldahl Nitrogen						●		
Lead	Pb					●		
Level				■				
Lithium	Li					●		
Magnesium	Mg					●		
Manganese	Mn					●		
Mercury	Hg					●		
Methylene Blue Active Substance	MBAS							
Molybdenum	Mo					●		
Nickel	Ni					●		
Nitrate	NO_3					●		
Nitrite	NO_2							
Odor								
Oil & Grease	OLGR					●		
Organic Carbon, Dissolved	DOC					●		
Organic Carbon, Total	TOC							
Ortho-Phosphorus (Phosphate)	PO_4							
Pesticides								
pH	pH					●		
Phenols						●		
PNA	PNA						▲	
Potassium	K					●		
Rubidium	Rb							
Sediment Characterization								
Selenium	Se					●		
Scandium	Sc							
Silica	SiO_2							
Silver	Ag					●		
Sodium	Na					●		
Solids, Dissolved	TDS					●		
Solids, Suspended	TSS							
Strontium	Sr					●		
Surfactants								
Sulfate	SO_4					●		
Sulfide	SO_2							
Temperature (°C)								
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti							
Tungsten	W							
Turbidity								
Vandium	V							
Yttrium	Y							
Zinc	Zn					●		
Zirconium	Zr							
Radioactivity								
Gross Alpha (pcl)						●		
Radium 226	Ra226					●		
Natural Uranium	U					●		
Gross Beta								
Cesium	Ce137							
Sr90								
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. hydrophobic Bases								
b. Hydrophobic Acids								
c. hydrophobic Neutrals								
d. hydrophilic Bases								
e. hydrophilic Acids								
f. hydrophilic Neutrals								

*Group 1: WY01, WY03, WG10, WY12, WY17, WY45, WY46, WY52, WY54, WY61, WY62, WY81, WY91

Group 2: WY64 thru WY72, WY75 thru WY79

SYMBOLS:

- ● Applies to Group 1.
- ▲ Applies to stations and species to be identified.
- ■ Applies to all stations.

changes and, if changes become evident, to determine if they are attributable to the development of the C-b Tract.

5.3.4.3 Experimental Design

Water quality data from the bedrock wells are ordinarily obtained and analyzed for potential changes by linear regression modeling. Time sequence graphs are usually prepared for those constituents that show linear trends with respect to time.

5.3.4.4 Discussion

During the 1981 water year, water quality samples were discontinued in order to preserve continuity in the water levels before the reinjection test. No water quality samples were available during late fall, winter, or spring of 1980-1981. The single sample, taken in July of 1981, was reported in Development Monitoring Report #7, dated January 15, 1982.

The data from the single sample were used in the application of the multiple-trilinear diagram technique (Piper 1953) on a trial basis. This method allows the reduction of water quality results to a single number that may be compared and plotted with other data. Figure 5.3.4-3 is a combined trilinear diagram for water quality data taken since the recompletion of the bedrock wells. The cations are plotted on the left half of the diagram, and anions are shown on the right. These data are based upon only one water quality sample, therefore the analysis must be considered a tentative and preliminary application of the technique.

5.3.5 Water Management

5.3.5.1 Scope

The management of water produced in excess of requirements was discussed in Section 5.2.6.1 and in Volume 1. Discharge of mine water continued during the 1981 water year in accordance with the NPDES permit. Water quality analyses of water used during reinjection are described in Appendices 2B and 2D. Seepage monitoring well WW12 was recompleted in 1980 and is now designated WW22. Locations of these wells were shown in Figure 2.2-1.

5.3.5.2 Objectives

Water quality is sampled at WN40 to ensure compliance with the NPDES permit. Wells WW12 and WW13 are sampled to determine the effects of seepage from Ponds A, B and C on the water quality of the Uinta aquifer.

5.3.5.3 Experimental Design

Samples were obtained and analyzed according to the parameters and frequency shown in Tables 5.3.5-1 and 5.3.5-2. The data

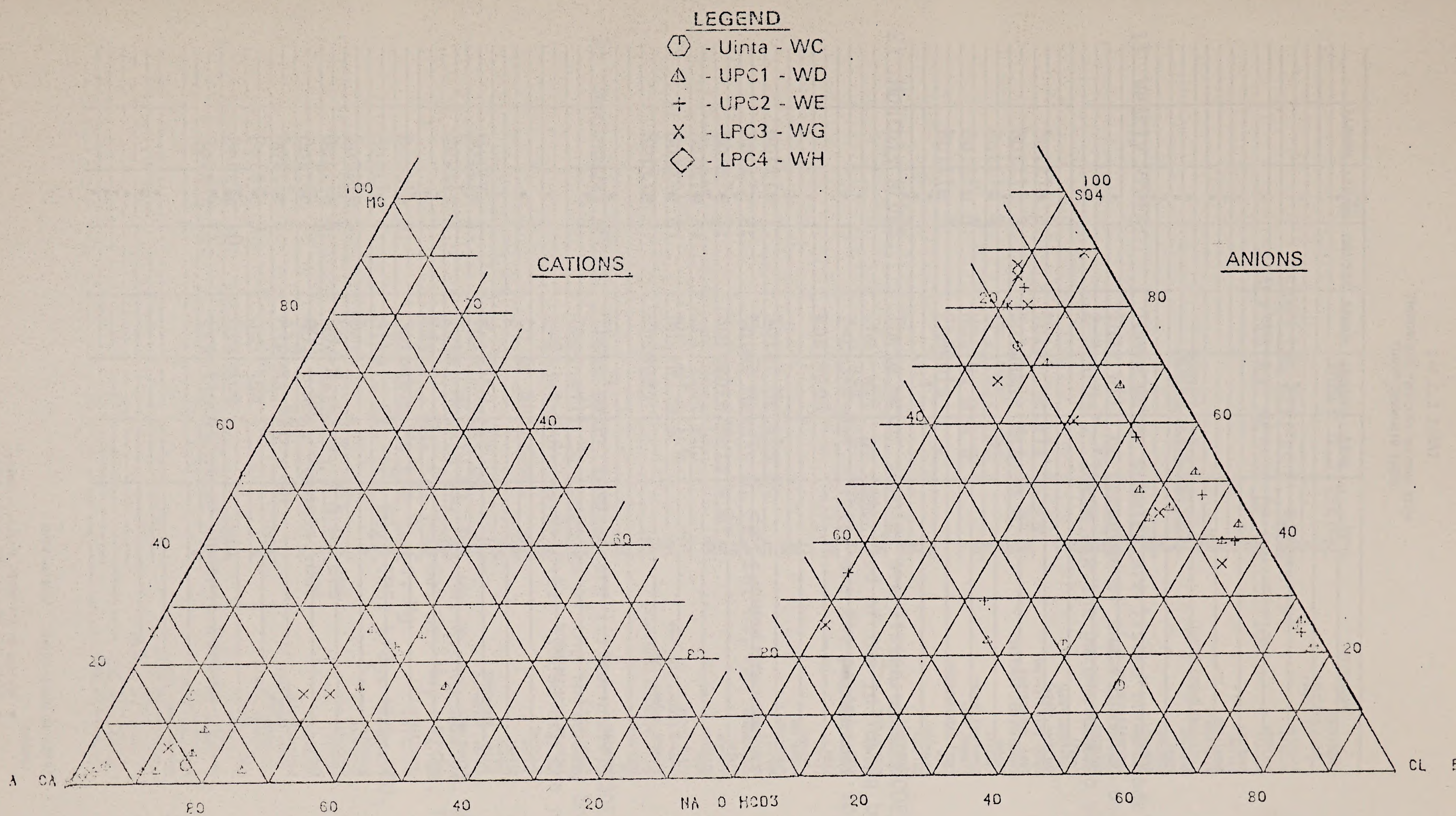


Figure 5.3.4-3. Multiple-Trilinear diagrams of selected water quality constituents for C-B bedrock wells for one sample taken after the reinjection test in 1981.

TABLE 5.3.5-1

WATER SAMPLING FREQUENCY REQUIREMENTS
NPDES DISCHARGE POINT*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$					●		
MO Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al		●			▼		
Ammonia	as NH_3		●					
Antimony								
Arsenic	As					▼		
Bacteria	Sb							
Barium	Ba					▼		
Beryllium	Be					▼		
Bicarbonate	HCO_3					●		
Biological Oxygen Demand	BOD							
Bismuth	Bi					▼		
Boron	B		●			●		
Bromine	Br					●		
Cadmium	Cd					▼		
Calcium	Ca			●		●		
Carbonate	CO_3							
Chemical Oxygen Demand	COD					●		
Chloride	Cl	●				●		
Chromium	Cr					▼		
Cobalt	Co							
Coliform, Fecal								
Coliform, Total								
Color (Not Precise)						●		
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC							
Copper	Cu			●		▼		
Cyanide	Cn					●		
Dissolved Oxygen	DO							
Element Scan								
Fecal Streptococcus								
Flow		■						
Fluoride	F		●			●		
Gallium	Ga					▼		
Germanium	Ge					▼		
Hardness (Ca, Mg)								
Hydroxides	OH							
Iodine	I							
Iron	Fe		●			▼		
Kjeldahl Nitrogen						▼		
Lead	Pb					▼		
Level								
Lithium	Li					▼		
Magnesium	Mg					●		
Manganese	Mn					▼		
Mercury	Hg			●		▼		
Methylene Blue Active Substance	MBAS							
Molybdenum	Mo					▼		
Nickel	Ni					▼		
Nitrate	NO_3					●		
Nitrite	NO_2					●		
Odor						●		
Oil & Grease	OLGR	▲	●			●		
Organic Carbon, Dissolved	DOC					●		
Organic Carbon, Total	TOC							
Ortho-Phosphorus (Phosphate)	PO_4							
Pesticides								
pH	pH	●						
Phenols			●			●		
PNA	PNA							
Potassium	K					▼		
Rubidium	Rb							
Sediment Characterization								
Selenium	Se					▼		
Scandium	Sc							
Silica	SiO_2					●		
Silver	Ag			●				
Sodium	Na					▼		
Solids, Dissolved	TDS		●			▼		
Solids, Suspended	TSS		●					
Strontium	Sr					▼		
Surfactants								
Sulfate	SO_4					●		
Sulfide	SO_2					●		
Temperature (°C)						●		
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti					▼		
Tungsten	W							
Turbidity								
Vandium	V					▼		
Yttrium	Y							
Zinc	Zn			●		▼		
Zirconium	Zr					▼		
Radioactivity								
Gross Alpha (pCl)						●		
Radium 226	Ra226					★		
Natural Uranium	U					★		
Gross Beta						●		
Cesium	Cs137					★		
Sr90						★		
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. Hydrophobic Bases						●		
b. Hydrophobic Acids						●		
c. Hydrophobic Neutrals						●		
d. Hydrophilic Bases						●		
e. Hydrophilic Acids						●		
f. Hydrophilic Neutrals						●		

*NPDES discharge point: Station WN40

SYMBOLS:

- ● Applies to all NPDES discharge points.
- ■ Daily flow also at USGS station WUG1.
- ▼ Total Values.
- ★ Required if gross alpha or gross beta increase by 20% above average.
- ▲ Visual analysis of presence of oil and grease only.

TABLE 5.3.5-2

SAMPLING SCHEDULE, PARAMETERS
ANALYZED AND METHOD OF COLLECTION

NPDES Discharges

1) Weekly NPDES: These water samples are listed under Code 10. They will be composed of the following bottles: 2-3-4-6-7. These are the parameters to be analyzed.

Bottle 2:	Total Metals B, Fe
Bottle 3:	Soluable Metals Al
Bottle 4:	tF, TSS, TDS
Bottle 6:	NH_3-N, O & G
Bottle 7:	Phenols

2) Monthly NPDES: These water samples are listed under CODE 11. They will be comprised of the following bottles: 1-2-3-4-6-7. These are the parameters to be analyzed.

Bottle 1:	Total Metals Hg
Bottle 2:	Total Metals B, Fe, Cd, Cu, Ag, Zn
Bottle 3:	Soluable Metals Al
Bottle 4:	tF, TSS, TDS
Bottle 6:	NH_3-N, O & G
Bottle 7:	Phenols

3) Semiannual NPDES: These water samples are listed under CODE 12. They will be composed of the following bottles: 1-2-3-4-5-6-7-8-9-10-11. These are the parameters to be analyzed.

Bottle 1:	Total Metal Hg
Bottle 2:	Total Metals As, Fe, Mn, K, Na, Sr, Al, Be, Ba, Bi, Cd, Cr, Cu, Pb, Li, Ga, Ge, Mo, Ni, Se, Ti, V, Zn, Zr
Bottle 3:	Soluable Metals B, Ca, Mg
Bottle 4:	Alkal, Cl, tF, SO_4, TDS, SiO_2, HCO_3, CO_3
Bottle 5:	Br
Bottle 6:	NH_3-N, Kj-N, O & G, COD
Bottle 7:	NO_3 + NO_2, Phenols, DOC
Bottle 8:	Alpha, Beta, Th
Bottle 9:	Sulfide
Bottle 10:	Cyanide
Bottle 11:	Fractionation of Organic Carbon

from the analysis were then analyzed by inspection of plots of the concentrations with time, and by the application of a linear regression model as an initial screen for the existence of linear trends.

5.3.5.4 Results and Discussion

NPDES discharge of mine water continued during the 1981 water year in accordance with requested permit criteria revision (letter submitted 10/19/80 to the Colorado WQCC) requesting change on the basis of an agricultural stream use classification for Piceance Creek. Meanwhile, the existing permit, which would have expired December 31, 1980, has been temporarily extended for two years without change or response to C.B.'s requests to the WQCC for change.

Table 5.3.5-3 shows the data from the analysis of weekly water quality samples required by the NPDES permit.

Table 5.3.5-4 shows the results of water quality analyses averaged over the 1981 water year for the seepage monitoring wells WW12 before completion, WW13 and WW22 after recompletion. The range of variation within the undisturbed system was not established. These four tests are, nevertheless, the only data currently available.

5.3.6 Raw Mined Oil Shale Stockpiles and Dumps

A field leaching study of raw mined oil shale continued during the 1981 water year. A summary of this study is provided in Section 8.11.3.

5.4 Quality Assurance

5.4.1 Scope and Purpose

C.B. began a formal intra-laboratory quality control program in April of 1979. The "Handbook for Analytical Quality Control in Water and Wastewater Laboratories", which was published by the U.S. Environmental Protection Agency in June of 1972, served as a foundation upon which the program was based.

The purpose of the quality control program is to monitor and control all of the factors which contribute to the final analytical result. The program continually monitors the degree of truth or reliability of the results which are reported.

5.4.2 Analytical Methods

Analytical methods used by the C.B. Laboratory have been documented by the U. S. Environmental Protection Agency as approved methodologies, under the National Pollution Discharge Elimination System Permit Program.

These procedures are obtained from five primary sources; Standard Methods for the Examination of Water and Wastewater, 14th Edition, EPA Methods for Chemical Analysis of Water and Wastes, 1979; Part 31, ASTM Water,

TABLE 5.3.5-3

C-b TRACT NPDES WATER QUALITY SAMPLES WEEKLY ANALYSIS

LOC	YR	MO	DY	FLOW (GPM)	LAB TOTL SUSS SOLIDS (MG/L)	TOTAL DISSOLVED SOLIDS (MG/L)	TOTAL F (MG/L)	TOTAL B (MG/L)	AMMONIA AS N (MG/L)	TOTAL PHENOL (MG/L)	AL (MG/L)	TOTAL FE (MG/L)	OIL AND GREASE (MG/L)	PH
WN40	80	12	4		34.0	1300.0	19.00	.70	1.40	-.001	-.1	.20	4	8.20
			17		3.0	1300.0	20.00	.70	.60	.001	.2	.20	6	7.50
			23		21.0	1400.0	19.00	.80	1.00	.003	.4	.10	5	7.40
			30		18.0	1300.0	20.00	.90	1.20	.002	.1	.10	1	8.30
	81	1	7		7.0	1400.0	18.00	.80	1.20	.001	.2	.10	6	7.10
			14		5.0	1400.0	18.00	.80	1.00	.001	.4	.04	2	7.30
			21		5.0	1400.0	20.00	.80	1.20	.002	.1	-.02	4	7.00
			28		13.0	1500.0	19.00	.80	1.00	-.001	.8	.20	-1	8.20
		2	4		-1.0	1300.0	20.00	.70	.70	.004	-.1	.03	-1	7.60
			9		17.0	1400.0	18.00	.70	.90	-.001	.1	.07	2	6.90
			11		11.0	1500.0	20.00	.80	.90	-.001	.2	.08	-1	6.70
			18		20.0	1300.0	19.00	.80	1.00	.005	-.1	.30	2	8.00
			25		10.0	1400.0	18.00	.80	1.00	.002	.1	.20	1	8.20
		3	4		-1.0	1400.0	19.00	.80	.90	.002	-.1	.10	3	7.90
			11		4.0	1500.0	19.00	.70	1.10	-.001	-.1	.20	-1	6.40
			18		13.0	1400.0	19.00	.70	.60	.004	-.1	.20	-1	7.10
			25		4.0	1400.0	19.00	.70	1.00	.002	-.1	.20	-1	6.90
		4	1		14.0	1300.0	19.00	.80	1.30	-.001	-.1	.07	-1	8.90
			8		29.0	1300.0	19.00	.60	.80	-.001	-.1	.12	2	8.20
			22		77.0	1400.0	18.00	.70	1.20	.002	.2	.30	7	8.70
		6	10		29.0	1300.0	19.00	.80	.60	-.001	-.1	.30	-1	8.70
			18		9.0	1300.0	19.00	.80	.60	.008	-.1	.20	8	9.00
			24		2.0	1300.0	19.00	.80	.80	.007	-.1	.07	2	8.91
		7	1		6.0	1300.0	18.00	.80	.60	.001	-.1	.20	-10	8.74
			8		9.0	1300.0	19.00	.80	1.10	-.001	-.1	.20	-10	8.72
			15		15.0	1300.0	19.00	.90	.60	.001	-.1	.10	-10	8.92
			22		3.0	1300.0	20.00	.70	.70	.002	-.1	.20	-10	8.36
			29		9.0	1300.0	20.00	.80	1.00	.005	-.1	.05	-10	8.66
		8	5		20.0	1300.0	19.00	.80	.80	.001	-.1	.07	-10	8.76
			11		33.0	1400.0	19.00	.70	.50	-.001	-.1	.10	-1	9.33
			19		6.0	1400.0	20.00	.50	1.20	.004	.1	.04	-10	7.37
			26		7.0	1300.0	20.00	.20	1.20	.004	-.1	.08	-10	7.55
		9	2		6.0	1300.0	20.00	.70	.50	.004	-.1	.05	-10	8.02
			9		1.0	1300.0	20.00	.60	.70	.003	.2	.09	-10	
			16		17.0	1400.0	21.00	.30	1.20	.011	-.1	.11	-10	7.84

Negative sign (-) indicates "less than"

TABLE 5.3.5-4

WATER QUALITY FROM SEEPAGE MONITORING WELLS

1981 Water Year Average (mg/l)

	WW12*	WW13	WW22
T Alk	110.0	386.4	82.25
Al	-.100	-.100	
NH_3	11.5	1.716	23.75
As	-.020	-.020	-.020
Ba	-.50	-.50	
HCO_3	-1.0	318.75	-1.0
CO_3	97.0	71.625	54.0
BOD	38.5	32.5	
Br	-.100	-.100	
Hardness	150.0	850.0	
Na	75.0	206.6	172.5
Mg	17.0	74.7	23.25
Ca	11.0	32.5	77.2
Kjeld-N	12.0	1.48	32.75
Zn	-.020	-.020	
Pb	-.020	-.020	
Li	-.050	.06	
Mn	-.020	.24	.015
Fe	.03	.128	3.775
F	.90	-.04	1.45
Mo	.015	.15	
Ni	.0	.005	
NO_3	-.5	-.3	-1.0
Oil	11.5	4.5	
Phenol	.012	.002	
K	3.9	4.05	42.0
B	.1	.25	.2
TDS	450.0	951.6	982.5
Sr	.5	2.4	
SO_4	240.0	430.0	
Cl	15.0	11.05	51.0
COD	27.5	.15	
Cr	-.020	-.020	
Cu	-.020	.020	
DO	5.6	4.286	4.25
DOC	10.5	4.6	39.75
pH	8.95	7.7	9.375
Sp. Cond.	835.0	1408.57	1392.5
Temp.	11.25	16.25	18.0
SiO_2	-1.0	6.44	-1.0
Co	.0	-.020	
OH	10.0		

*Well recompleted 11/80, refer to WW22

1977; U.S.G.S. Methods of Determination of Inorganic Substances in Water and Fluvial Sediments, 1979; U.S.G.S. Methods of Analysis of Organic Substances in Water, 1972.

5.4.3 Sample Handling and Reporting of Results

Samples received at C.B. laboratory are immediately inventoried and stored as is appropriate. Each sample is then logged in a permanent laboratory logbook and given a unique number. The sample is preserved for analysis in the field. All raw analytical data analyses are entered in bound lab notebooks. These books are used by laboratory personnel for the completion of the analysis and contain the following items:

- Parameter
- Sample identification
- Date sample analyzed
- Time sample analyzed
- Analyst - signature
- All calibration data
- All readout data (ABS, volume titrant, etc.)
- All calculations
- Final results

The analyses are then started on the critical parameters. When the analysis of each respective parameter is completed, the sample bottle is placed in a storage area according to parameter where it remains for a 4-week period, after which the sample is disposed of. Duplicate reference and spike samples are run along with analyses routinely. These reference duplicates and spike samples are then checked at the end of the each day to see that each of the analyses are in control. Each of these is then logged in the Q.C. reference books. At the same time, the results are then calculated, checked for discrepncies, re-analyzed if out of norm, and pertinent information is summarized. The report is then made out to the originator. Depending upon the multitude of analyses run, this report is sent out within two weeks of having received the sample, for NPDES samples, and thirty days for other samples.

5.4.4 Instrumentation and Calibration

In order to insure that all instrumentation used for analytical procedures is operating at optimum conditions, C.B. has effected a Preventative Maintenance program.

Perkin-Elmer Corporation and Jarrel-Ash Division are contracted by C.B. to perform a preventative maintenance check twice a year on the optical and electrical components of our atomic absorption instrumentation. In addition, a check is performed on all balances twice a year. C.B. has a contract with Hewlett Packard and Varian to perform routine preventative maintenance on the gas chromatographs.

Instructions giving a step-by-step procedure for the calibration and operation of each instrument are given in a lab method book for each technician to follow.

Laboratory needs such as distilled water, light, heat, electricity, temperature and vibrations are controlled to insure optimum working conditions.

All instrumentation used for the completion of the methodologies referenced above have been catalogued according to brand name and model number.

5.4.5 Reagents, Solvents, and Gases

All organic and inorganic reagents used in the laboratory for the preparation of primary standards and other solutions are Analytical Reagent Grade or purer. A monthly inventory of reagents and chemicals is conducted. Reagents and solvents are stored in borosilicate glass bottles, alkaline solutions are kept in plastic polyethylene containers. Reagents and solvents sensitive to light are stored in dark bottles or in a cool, dark place. Chemicals are dated upon receipt and opening.

The concentration and composition of many solutions are susceptible to changes over short period of time. All reagents and standards are properly labeled and dated when prepared, to monitor their shelf life.

Standards are run with each set of samples for every analytical procedure to insure that the reagents used have not degraded or undergone any contamination.

Fuel and oxidant gases used for atomic absorption work are of commercial grade. Air is supplied by a compressor and passed through a filter to remove any oil, water or possible trace metals from line. For certain determinations, reagent grade nitrous oxide is used.

The laboratory water system consists of a demineralizer system for general purpose uses, with a Corning ion exchange column, backed with an activated charcoal filter for certain applications. Specific conductance measurements are performed routinely to insure purity. For trace metals analyses, distilled water from an all glass still is used.

5.4.6 Glassware

All glassware used in the laboratory for volumetric and colorimetric methods of analysis are borosilicate Kimax or Pyrex brand glass. Volumetric glassware is Class A, meeting National Bureau of Standards specifications for capacity and delivery.

The method of cleaning glassware is dependent upon both the substances that are to be removed and the determination to be performed. Water-soluble substances are washed out with laboratory detergent and warm water and rinsed with successive small amounts of tap and finally distilled water. Other substances more difficult to remove require the use of detergent and a dichromate cleaning solution. For certain determinations, especially

trace metals, the glassware is rinsed with a 1 + 1 nitric acid-water mixture. This operation is followed by thorough rinsing with distilled water.

5.4.7 Sample Preservation

In order to maintain the integrity of the samples from the time it is collected until it is received in the laboratory for analysis, sample containers used by C.B. for the collection of samples, contain the proper perservative where required.

5.4.8 Personnel

The C.B. Grand Junction Laboratory maintains a professional attitude of its laboratory staff. The laboratory staff consists of both graduate chemists and technicians.

In order to provide accountability for quality, well defined areas of responsibility are assigned to each analyst. To insure that each analyst is familiar with his or her job function, C.B. has implemented a series of laboratory seminars which review methodology, theory and laboratory techniques. In addition, routine quality control meetings are held with the laboratory staff to monitor the progress of the quality control program and implement corrective measures where needed.

5.4.9 Control of Analytical Performance

During normal laboratory operation, a system to evaluate the daily performance and to document the validity of the data being produced is required. Systematic daily checks are needed to show that reproducible results are being obtained (precision) and that the methodology is actually measuring the true concentration of the sample (accuracy).

In order to document precision, it is necessary to run duplicate samples. C.B. runs duplicate and spike analyses on actual wastewater samples which cover a range of concentrations and a variety of interfering materials on fifteen percent of the samples processed by the laboratory.

Precision and accuracy control charts are being maintained. Up-to-date precision and accuracy data are plotted by means of quality control charts to determine if valid, questionable, or invalid data are being generated from day to day. At least fifteen to twenty sets of spike sample data for each parameter are required for the construction of a quality control chart. With this data the quality control chart is constructed statistically, using the Shewart Method. Information pertaining to parameter, methodology, name and date constructed, range, standard deviation, formulas used for determining upper and lower limits, are included in the chart.

5.4.10 Intra- Inter-Laboratory Testing

To obtain a reliable measure of our intra-laboratory quality control program, it is necessary to compare individual performance against other laboratories.

C.B. is active in intra-laboratory testing on two levels. First, we are actively participating in the Environmental Protection Agency "Reference Sampling Program". In this program the EPA distributes, upon request, ampules containing known concentrations of a wide variety of parameters. The proper dilutions are made for each ampule and the analysis conducted in a routine manner. The correct answers are provided with the ampules to verify the comparability of the results obtained.

Second, we purchase from Environmental Resource Associates WasteWatR and Potable WatR reference samples. These are handled similarly to the EPA reference samples. A $\pm$ 10% for routine analysis is considered generally acceptable for EPA reference samples. However, this may vary based on the parameter and concentration range. Environmental Resource Associates samples have listed acceptable ranges.

The laboratory has also analyzed samples as part of a U.S.G.S. study. This study was designed to measure overall laboratory performance and compare it to other laboratories in this geographic area. Results of this study have not been published.

5.4.11 Summary

Using these procedures, C.B. strives to provide the most reliable results possible. Approximately fifteen percent of the laboratory's time is needed to sustain the Quality Control program. Quality control is not something to attain, but to retain, dictated by the continuous improvements and change in methodologies and procedures. It is through this system of continual improvement that C.B. maintains the quality of its results.

6.0 AIR QUALITY AND METEOROLOGY

6.1 Introduction and Scope

The monitoring program for air quality and meteorology was carried out in accordance with the provisions of the Development Monitoring Plan, as modified by conditions of approval issued by the Oil Shale Supervisor. Thru September, 1981, two ambient air stations monitored gaseous constituents, particulates, and various meteorological variables. A third station (AB26) became operational in October. A 60-meter meteorological tower is located at Air Quality Station AB23. The tower has wind speed and direction instruments at three levels, and also has instruments for temperature and delta temperature. Meteorological data were also gathered at two mechanical weather stations. All the above systems are operated on a continuous basis. Visual range measurements were made using a method combining photography and microdensitometry. Measurements were made in the Spring and Fall. Section 6.2 discusses the results from the air quality monitoring program. Section 6.3 discusses the supporting meteorological measurements. Section 6.4 discusses quality assurance.

6.2 Ambient Air Quality

Three categories of the ambient air quality program include gaseous constituents, particulates, and areawide visibility.

6.2.1 Gaseous Constituents

6.2.1.1 Scope

Continuous monitoring of gaseous constituents in the ambient air on and near the C-b Tract included:

Sulfur Dioxide (SO_2)
Hydrogen Sulfide (H_2S)
Ozone (O_3)
Carbon Monoxide (CO)
Oxides of Nitrogen (NO_x)
Nitrogen Dioxide (NO_2)
Nitric Oxide (NO)

Monitoring of these constituents is required under the Lease stipulations. Data collected during 1981 have been reduced and analyzed to determine trends in or relationships among any of the variables.

6.2.1.2 Objectives

The objectives of the analyses reported here are: to demonstrate compliance with applicable ambient air quality standards, to detect any long-term or seasonal trends in monitored variables, and to attempt to identify sources of pollutants if levels of those pollutants are significantly above baseline levels.

6.2.1.3 Experimental Design

The air quality development monitoring network is shown in Figure 6.2.1-1; systems-dependent stations are currently inactive. Station AB23 is equipped to monitor the constituents listed in Section 6.2.1.1, and has provided a continuous air quality record since the beginning of the baseline monitoring period. Station AB20 was equipped during 1979 to measure all constituents except the sulfur gases (SO_4 and H_2S). Station AB26 measures all air quality constituents. The monitoring at all sites is accomplished with continuous analyzers. The constituents monitored at each site, the frequency of data collection, and the start-up dates are shown in Tables 6.2.1-1 and 6.2.1-2.

The analyzers in all stations are, where applicable, the E.P.A. reference or equivalent methods for their respective constituents. Quality assurance procedures have been provided in the Development Monitoring Data Reports. Specifications for all instruments are listed in Table A6.2.1-1. Positive data values below the instrument detection limit were not entered as zeroes into the data base; the actual values were entered. Negative values appearing on magnetic tape were entered as zeroes.

6.2.1.4 Methods of Analysis

The methods used in the analysis of air quality data are as follows:

6.2.1.4.1 Concentrations as Time Histories

Concentration time histories are analyzed to detect variation in the data over time. Such patterns may be composed of three or more components. Almost all environmental variables will have a distinct random component of time-based variation. The complex interrelationships among these variables will assure some level of unpredictable behavior. A second frequently-seen component is periodic variation, such as a seasonal cycle. Gaseous constituents related to meteorological variables will show a detectable periodic component synchronized with seasonal variations in meteorology. Superimposed on these two patterns may be a trend component indicating an increase or decrease with time in the level of an air contaminant. Visual representations of the monitored data for the gaseous constituents at Stations AB20 and AB23 are presented in the form of time-series plots submitted twice annually to the Oil Shale Office and are not repeated here. Peak values and monthly means are presented to provide a general reference for air quality at the Tract. Comparisons with standards are discussed in the next section.

A linear regression model was applied to air quality data with respect to time to provide initial screening for linear trends. Results of this analysis are discussed in 6.2.1.5.1.

6.2.1.4.2 Comparison with Standards

Maximum concentrations from air quality monitoring were compared with ambient air quality standards for the respective averaging time of each standard.

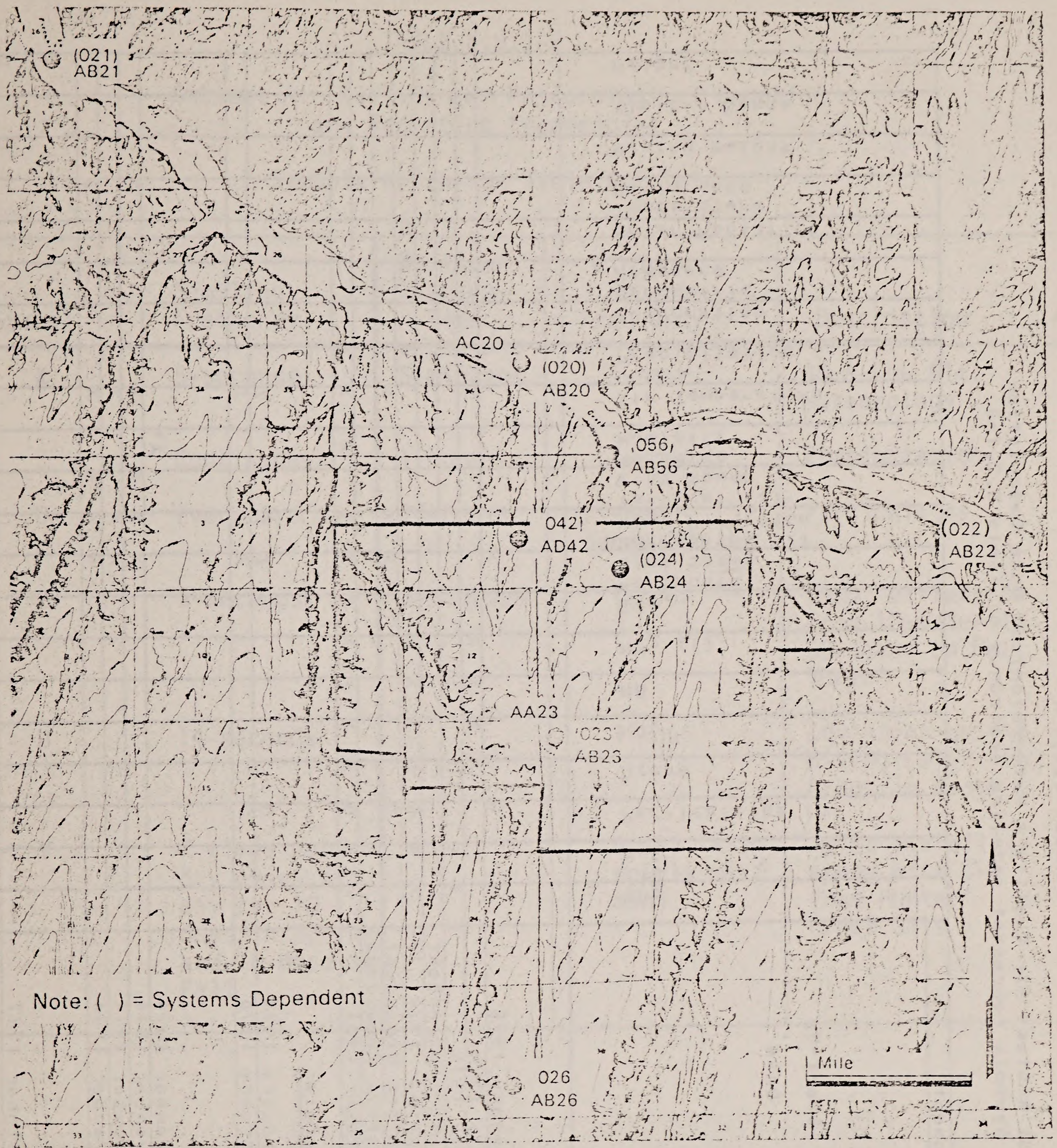


FIGURE 6.2.1-1
AMBIENT AIR QUALITY DEVELOPMENT MONITORING NETWORK

TABLE 6.2.1-1

1981 Ambient Air Quality & Meteorological Data Description
Symbols represent sampling frequency on Table 6.2.1-2

Measurement: Category and Location	Start-Up Date	SO_2	H_2S	Particulates (3)	Ozone	NO_x	NO	NO_2 (1)	CO	Horizontal Wind Speed	Horizontal (2) Wind Direction	Vertical (2) Wind Speed	Relative Humidity	Air Temperature	Precipitation	Evaporation	Barometric Pressure	Solar Radiation	Temperature Difference	Mixing Height	Visible Range	Height
Air Quality Trailer																						
AB20	a) January 1978			O						X	X				Z							
	b) July 1978				X	X	X	X	X					X								
	c) July 1979	X																				
AB21	Systems Dependent																					
AB23	November 1974	X	X	O	X	X	X	X	X						Z		X	X				
AB24	a) Systems Dependent			O						X	X			X								
	b) Systems Dependent	X	X																			
AB26	October 1981	X	X	O	X	X	X	X	X	X	X		X	X	Z							
Weather Station & Hi Vol Sampler																						
AD42	February 1978			O						Z	Z			Z								
AD55	February 1978			O						Z	Z			Z								
Meteorological Tower @																						
3m	November 1974												X*									
10m	November 1974									X	X	X		X					Z			
30m	November 1974									X	X			X								
60m	November 1974									X	X	X		X					Z			
Upper Air Studies																						
Acoustic Radar 020	October 1977																			U		U
Visibility Sta 060	April 1978																				V	

* @ 1m (1) $(NO_2) = (NO_x) - (NO)$ (3) Also Size Distributions During Visibility Study
(2) Standard Deviation calculated

TABLE 6.2.1-2

Ambient Air Quality and Meteorological Sampling and Reporting Frequencies

Symbols appear on Table 6.2.1-1

Symbol	Sampling Frequency	Minimum Average Time	Minimum Report Frequency	Description
X	5-seconds	5-minutes	1-hour	AQ & Low Alt. Meteorology
Z	Continuous	1-hour	1-hour	Precipitation
O	Every 3rd day	24-hours	24-hours every 3rd day	Particulates
2	5-seconds	5-minutes	1-hour	Temp. difference from 10-meter to 60-meter on Met. Tower
U	14-seconds		1-hour	Inversion Height/ Mixing Layer from Acoustic Radar
V	7 times per day every 6th day for 10 days in Spring and 10 days in Fall	Hourly	Daily (with hourly max/ min)	Joint Visibility study with C-a from Hunter Creek Site

6.2.1.4.3 Correlation with Wind Speed and Direction

Correlation of wind speed and direction with measured concentrations of gaseous constituents may tend to show patterns leading to identification of contributing sources. Regional air contaminant levels generally will not display consistent variation with wind direction. The influence of a major air contaminant source will be most pronounced within a given sector of wind direction, the sector being smaller for sources closer to the monitoring site due to dispersion effects which accompany transport of air contaminants. The effect of wind speed is less direct. One way in which wind speed relates to measured concentrations is through influence on atmospheric stability and therefore on contaminant dispersion. This relationship can be difficult to predict. High winds may aid in dispersion and thereby reduce concentrations, but they may also transport polluted air parcels. To circumvent this difficulty, results are presented as pollutant concentration roses, i.e., concentration as a function of wind direction.

The gases monitored at the C-b Tract are not the products of nearby sources, but rather are the result of dispersion of many sources over a wide region with concentrations near instrument lower detection limits. For this reason, wind correlations are not presented for sulfur gases, nitrogen oxides, and carbon monoxide.

6.2.1.4.4 Comparison of Maximum and Mean Concentrations

A comparison of maximum and mean concentrations of air contaminants may provide some insight into the causal factors contributing to observed levels of those contaminants. There are three cases to consider: (1) the ratio of maximum to mean is close to one, and both maximum and mean values are low compared to ambient standards; (2) the ratio is close to one, but both maximum and mean are significant, compared to ambient standards; and (3) the ratio is high, and the mean is low compared to ambient standards.

In the first case, the closeness of maximum to mean indicates that the factors contributing to ambient concentrations are relatively consistent. Low levels observed indicate the absence of substantial contaminant sources near the monitoring site. Often, this situation is indicative of regional air contaminant levels in clean-air areas. Relatively minor local influences combined with highly dispersed contributions from distant sources result in stable, low levels of air contaminants.

The second case will most often occur where there is a geographical concentration of major sources of air contaminants, particularly where there is little variation in meteorology. This situation will frequently correlate with a high degree of urbanization or industrial development in the immediate vicinity of a monitoring site or in an area consistently upwind of the site. The case not mentioned, i.e., the ratio, maximum and mean all high, would fit the same pattern of analysis, except for a higher degree of meteorological influence or more variable contributions.

The third case, a low mean value coupled with a high ratio indicates the absence of nearby major stationary sources of air contaminants. Unlike the first case, however, the high ratio of maximum to mean is indicative of some major influence which is subject to time variation. One example would be the short-term effects of a portable source. Relatively infrequent natural phenomena such as carbon monoxide and particulates from forest fires, or downward entrainment of stratospheric ozone are other examples. The consistent feature is the absence of effects of nearby urbanization.

6.2.1.5 Discussion and Results

6.2.1.5.1 Results of Analysis of Concentrations as Time Histories

To gain a general insight to levels of air quality at the Tract, peak hourly values obtained in 1981 (thru the data cutoff date of October) are as follows:

	Station AB23	AB20 (ug/m^3)
SO_2	31	16
CO	1800	1800
O_3	155	161
NO_x	64	23
NO	20	6
NO_2	45	17

To obtain insights regarding average conditions over time Tables 6.2.1-3a and 6.2.1-3b present monthly average values over 1980 and 1981.

For the sulfur gases, hydrogen sulfide and sulfur dioxide, excursions above the detection limit are infrequent and of short duration. This is consistent with past results in sulfur gas monitoring.

The oxides of nitrogen more frequently reach measurable levels, but daily mean values are often below the detection limit. The background concentration of ozone (discussed below) is sufficient to cause generally measurable nitrogen oxides, particularly nitrogen dioxide.

Carbon monoxide is probably the only gaseous constituent directly emitted into the atmosphere from Tract operations in sufficient quantity to be routinely measurable. Even so, daily means are often at or below the detection limit. There does not appear to be any pattern in the occurrence of peak levels.

Ozone is the only gas monitored consistently having a measurable mean concentration. Also, in the past it has closely approached the ambient air standard. This behavior is of interest because there are no development-related emissions of the type and magnitude to cause elevated ozone levels. The possible causes of ozone excursions are discussed in a later section.

Since ozone is the product of atmospheric reactions and also present in the stratosphere, rather than an emitted

TABLE 6.2.1-3a

Monthly Arithmetic Ambient Air Constituent Concentrations of Gases and Particulates (ug/m^3)

a) Station AB20

(1980)

Constituent	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.1	0.3
NO_3	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	2.0	2.0	3.0	0.8
O_3	36.0	32.0	45.0	64.0	66.0	67.0	58.0	56.0	57.0	49.0	37.0	25.0	49.3
CO	200.0	100.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	41.6
SO_2	2.0	14.0	9.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	1.0	5.0	2.9
Particulates	6.2	3.4	3.4	7.0	3.8	13.4	11.3	13.1	13.4	5.8	10.9	8.7	8.4+

(1981)

Constituent	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
NO	1.0	1.0	2.0	0.0	0.0	0.0	0.0	1.0	1.0	6.0	2.0	5.0	1.5
NO_2	1.0	1.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	4.0	3.0	1.0
O_3	32.0	71.0	69.0	49.0	80.0	75.0	84.0	63.0	68.0	55.0	52.0	79.0	64.8
CO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300.0	500.0	400.0	0.0	0.0	100.0
SO_2	1.0	1.0	2.0	0.0	7.0	6.0	0.0	5.0	6.0	1.0	4.0	5.0	3.2
Particulates	6.7	6.7	3.0	16.1	10.3	33.4	22.3	23.4	15.9	4.1	11.3	6.4	13.5+

+ Geometric

TABLE 6.2.1-3b

Monthly Arithmetic Ambient Air Constituent Concentrations
of Gases and Particulates (ug/m^3)
b) Station AB23

(1980)

Constituent	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
NO	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.1
NO_2	3.0	1.0	0.0	.0	0.0	0.0	1.0	1.0	0.0	2.0	1.0	3.0	1.0
O_3	61.0	72.0	79.0	87.0	80.0	78.0	76.0	76.0	80.0	78.0	70.0	66.0	75.2
CO	300.0	200.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	66.6
SO_2	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	2.0	1.0
H_2S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.0	2.0	0.0	0.2
Particulates	4.3	2.6	4.8	9.1	8.9	22.7	7.0	15.4	8.3	7.6	6.0	3.1	8.3+

(1981)

Constituent	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
NO	1.0	1.0	2.0	(1)	(1)	(1)	2.0	1.0	3.0	6.0	8.0	(1)	3.0
NO_2	2.0	1.0	1.0	(1)	(1)	(1)	0.0	0.0	1.0	5.0	7.0	(1)	2.1
O_3	77.0	90.0	89.0	105.0	91.0	86.0	76.0	71.0	72.0	59.0	51.0	56.0	76.9
CO	0.0	100.0	0.0	0.0	0.0	0.0	0.0	200.0	0.0	0.0	0.0	0.0	25.0
SO_2	2.0	2.0	0.0	0.0	0.0	0.0	2.0	7.0	5.0	1.0	1.0	1.0	1.8
H_2S	0.0	0.0	(1)	0.0	0.0	1.0	2.0	1.0	4.0	(1)	4.0	1.0	1.3
Particulates	6.0	7.5	6.9	12.4	12.8	26.2	33.4	24.2	16.3	3.7	11.2	6.6	14.3

+ Geometric

(1) Instrument malfunction for over 75% of month

substance, its concentration is subject to variation due to stratospheric down mixing or to changes in the intensity of insolation, providing the driving force for ozone-producing reactions. This results in a seasonal pattern in the ozone plots, with the highest mean concentrations in summer (particularly in the heat of the day), and lowest in winter. Over the history of ozone monitoring on-Tract, this seasonal pattern coupled with the large random component has been consistently present.

In a format suggested by EPA's SAROAD data base, statistical distributions of ozone along with the annual arithmetic mean and five highest hourly averages, ozone values are presented for calendar year 1979 through 1981 on Table 6.2.1-4.

Table 6.2.1-5 shows the results of the application of the linear model to air quality data with respect to time. The four values are defined in the figure legend. In those cases where the linear model did not fit the data, items three and four are left blank.

Short-term linear trends at a 5% level of significance are apparent at Station AB23 for NO, O_3, and H_2S; none existed for any parameters at AB20. Without exception even where a trend exists at the 5% level it is of no practical significance because the magnitude of the slope (ug/m^3/day) is so minute.

Long-term linear trends in sulfur dioxide or hydrogen sulfide were not apparent in the data. Trends in oxides of nitrogen were all slightly negative and existed only at AB20. Long-term trends in ozone data were slightly positive at AB23. Carbon monoxide exhibited negative long-term trends at both stations. Magnitude of all trends was again small enough to be of no practical significance.

In summary, monitoring of ambient gases during the period of this report produced little new information. Sulfur gases, nitrogen oxides and carbon monoxide continue to be present at low levels.

All linear trends where they exist are negligible in the practical sense. Ozone, while measured at significant levels, may be characterized as having a seasonal, background type of pattern, with large random variations compared to seasonal mean levels.

6.2.1.5.2 Results of Comparison of Maximum Concentrations with Ambient Standards

Table 6.2.1-6 lists the maximum measured concentrations of gaseous constituents for averaging times corresponding to standards for the past three years. For all but one of the gaseous criteria pollutants the maximum concentrations are well below the standards; the one exception is ozone. Only one expected exceedance occurred in the past three years; more than three are required to exceed the standard. This pattern of generally low values (excepting ozone) has existed since the beginning of ambient monitoring at the C-b Tract in the fall of 1974. This is consistent with the overall character of the region with very low population density and

TABLE 6.2.1-4
OXIDANTS (O_3) AT STATION AB23
C-b TRACT RIO BLANCO COUNTY
(1978 - 1981)

1978

Number Hourly Observations: 8081
Annual Arithmetic Mean (ug/m^3): 81.6
5-Highest Hourly Averages (ug/m^3):

	Value	Date	Hour Ending	
1.	160.9	8/27	Hour Ending	1800
2.	157.0	8/27	" "	1700
3.	153.0	8/27	" "	1900
4.	153.0	9/8	" "	1500
5.	149.1	9/8	" "	1800

Number of Hourly Concentrations in Ranges:

Range	No. of Values
0.0 - 2.9 (ug/m^3)	0
3.0 - 20.9	2
21.0 - 40.9	184
41.0 - 60.9	1290
61.0 - 80.9	2897
81.0 - 100.9	2200
101.0 - 120.9	1145
121.0 - 140.9	328
141.0 - 160.0	34
Greater Than 160.0	1

1979

Number Hourly Observations: 8693
Annual Arithmetic Mean (ug/m^3): 76.0
5-Highest Hourly Averages (ug/m):

	Value	Date
1.	245.8	1/20
2.	203.5	1/20
3.	195.2	1/20
4.	192.5	1/20
5.	164.6	1/20

Number of Hourly Concentrations in Ranges:

Range	No. of Values
0.0 - 2.9 (ug/m^3)	0
3.0 - 20.9	0
21.0 - 40.9	115
41.0 - 60.9	1335
61.0 - 80.9	3622
81.0 - 100.9	3167
101.0 - 120.9	443
121.0 - 140.9	6
141.0 - 160.0	0
Greater Than 160.0	5

1980

Number Hourly Observations: 8448
Annual Arithmetic Mean (ug/m^3): 75.3
5-Highest Hourly Averages (ug/m^3):

	Value	Date
1.	153.6	1/3
2.	130.5	1/3
3.	129.5	5/24
4.	129.5	6/5
5.	127.5	5/24

Number of Hourly Concentrations in Ranges:

Range	No. of Values
0.0 - 2.9 (ug/m^3)	5
3.0 - 20.9	6
21.0 - 40.9	157
41.0 - 60.9	1559
61.0 - 80.9	3685
81.0 - 100.9	2505
101.0 - 120.9	503
121.0 - 140.9	27
141.0 - 160.0	1
Greater Than 160.0	0

1981

Number Hourly Observations: 8226
Annual Arithmetic Mean (ug/m^3): 76.6
5-Highest Hourly Averages (ug/m^3):

	Value	Date	Hour Ending	
1.	155.0	5/5	Hour Ending	1200
2.	151.0	5/6	" "	1700
3.	149.0	3/27	" "	0800
4.	149.0	5/6	" "	1600
5.	147.0	3/27	" "	0600

Number of Hourly Concentrations in Ranges:

Range	No. of Values
0.0 - 2.9 (ug/m^3)	0
3.0 - 20.9	20
21.0 - 40.9	312
41.0 - 60.9	1820
61.0 - 80.9	2719
81.0 - 100.9	2244
101.0 - 120.9	919
121.0 - 140.9	176
141.0 - 160.0	16
Greater Than 160.0	0

TABLE 6.2.1-5

Summary of Air Quality Trend Analysis, Stations AB20 and AB23
Units are ug/m^3

Indicator Variable		Short-Term 020	Short-Term 023	Long-Term 020	Long-Term 023
SO_2	1.*	1.41/12	0.61/12	0.28/71	0.10/86
	2.	0.20	0.74	0.80	0.14
	3.				
	4.				
NOX	1.	1.35/12	2.88/9	3.63/66	1.40/80
	2.	0.23	0.06	0.002	0.36
	3.			-0.0032	
	4.			0.14	
NO	1.	0.89/12	2.02/9	2.36/66	0.90/81
	2.	0.08	0.04	0.01	0.35
	3.		0.0143	-0.0021	
	4.		0.4745	0.09	
NO_2	1.	0.62/12	1.05/9	1.30/66	0.72/80
	2.	0.28	0.08	0.0001	0.72
	3.			-0.0010	
	4.			0.22	
O_3	1.	33.05/12	39.21/12	28.56/66	37.27/85
	2.	0.43	0.002	0.22	0.01
	3.		-0.0602		0.0030
	4.		0.65		0.07
CO	1.	89.87/12	47.91/12	335.79/59	414.63/78
	2.	0.13	0.66	0.0001	0.0001
	3.			-0.3635	-0.4723
	4.			0.52	0.46
H_2S	1.		85.26/11	0.06/24	0.49/82
	2.		0.005	0.75	0.04
	3.		0.0067		
	4.		0.60		
TSP	1.	14.38/12	15.76/12	12.61/73	12.48/88
	2.	0.53	0.49	0.74	0.49
	3.				
	4.				

1.* Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α. (α = 0.05); if $\hat{\alpha} < \alpha$, trend exists
3. Slope - slope is (ug/m^3) per day
4. r^2 value

TABLE 6.2.1-6
Comparisons of Maximum Background Levels with Ambient Standards (Station AB23)

Applicable Standard	Constituent	Averaging Time	Standard Limit (ug/m3)	Maximum Reading (ug/m3) 1979	1980	1981
Colorado Ambient Air Quality Standards	Particulates	Annual	75	18.0	8.3	15.3
	Particulates	24-Hour	260	99.8	58.4	86.2
	H_2S	1-Hour	142	12.0	19.0	8.0
National Ambient Air Quality Standards						
Primary	SO_2	Annual 24-Hour	80 365	0.4 7.6	1.0 11.9	1.5 17.3
Secondary	SO_2	3-Hour	1300	16.4	13.1	18.3
Primary	NO_2	Annual	100	2.0	1.0	2.7(1)
Primary	Particulates	Annual 24-Hour	75* 260	13.3 99.8	8.3 58.4	10.6 86.2
Secondary	Particulates	Annual 24-Hour	60* 150	13.3 99.8	8.3 58.4	10.6 86.2
Primary	CO	8-Hour 1-Hour	10,000 40,000	1700 2900	3000 3800	1800 1800
Primary	Oxidant	1-Hour	240(2)	245.8(3)	153.6	155.0

*Geometric Mean
(1) 50% Data
(2) Standard is exceeded if $\geq$ 3 expected exceedances occur above this value over a three year interval.
(3) Represents the only exceedance to date

most development activities subject to stringent regulation of potential air quality impacts.

In the case of ozone, a combination of elevated background levels and observed excursions exists indicating down mixing from the stratosphere. During the period of this report, no new high values were established. Causes for high ozone concentrations were discussed in Volume III of the Final Baseline Report.

In summary, the results of monitoring the gaseous constituents through October demonstrate continued compliance with ambient air standards at the C-b Tract.

6.2.1.5.3 Results of Correlation of Air Quality Data with Wind Direction

Concentrations of ozone with respect to wind direction are provided as concentration roses in Appendix Figures A6.2.1-1 and A6.2.1-2 for Stations AB20 and AB23. Highest concentrations occurred in the prevailing wind directions (SSW-SW on Tract and up-and-down Piceance Creek). Seasonally highest concentrations occurred in the spring on Tract.

6.2.1.5.4 Results of Comparison of Maximum and Mean Concentrations

Table 6.2.1-7 lists the maximum and mean values and the ratio of maximum to mean for each gaseous constituent. Both maxima and means for nitrogen dioxide, sulfur dioxide, hydrogen sulfide, and carbon monoxide are small compared to their respective standards. For these constituents, the low values are more significant than the ratios in indicating the overall absence of significant sources of these air contaminants. However, in all four cases the maximum-to-mean ratio is considerably larger than it is for ozone. This shows that only in the case of ozone is the background concentration within an order of magnitude of the maximum value, indicating a greater consistency of monitored values.

6.2.1.6 Conclusions

(1) Compliance with State and Federal ambient air standards continued in 1981 at the C-b site for all constituents.

(2) Linear trends were shown for some parameters for both long-term and short-term data at the 5% level of significance. However all slopes were near-zero magnitude for the regression data so that no trends of practical significance exist.

(3) Sources of air contaminants on and near the C-b site include many small sources of combustion product gases and fugitive dust. No single source is of sufficient size to be detected on the basis of wind vs. concentration correlations.

TABLE 6.2.1-7

Maximum, Mean* and Max/Mean Ratio**
for Air Quality Constituents (ug/m^3)

Constituent	Symbol	Station AB20			Station AB23		
		Max	Mean	Max/Mean	Max	Mean	Max/Mean
Nitrogen Dioxide	NO_2	17	1.0	17	45	2.1	21
Sulfur Dioxide	SO_2	16	3.2	5	31	1.8	17
Hydrogen Sulfide	H_2S	-	-	-	18	1.3	14
Carbon Monoxide	CO	1800	100	18	1800	25.0	72
Ozone	O_3	161	64.8	2	155	76.9	2
Total Suspended Particulates	TSP	69	13.5	5	86	14.3	6

* Annual Arithmetic Means
** Based on 1-Hour Averages

6.2.2 Particulates

6.2.2.1 Scope

Monitoring of ambient particulates is required by the Oil Shale Lease Stipulations and by Federal and State Air Quality Regulations. Measurements were made at Stations AB20, AB23, AB26 and AD56. During visibility measurement days, size-distributed samples were taken at Station AB23.

6.2.2.2 Objectives

The objectives of the monitoring of ambient particulates are: (1) to demonstrate compliance with applicable regulations; (2) to determine whether long-term trends exist; and (3) to attempt to identify particulate sources.

6.2.2.3 Experimental Design

The EPA reference method for particulate monitoring, the high volume sampler, is employed at all stations to measure particulates. The samples are located such that the air intakes are approximately 4.6 meters above ground level. A Sierra particle sizing head is used in place of the standard filter assembly when taking size-distributed samples. As yet, there is no EPA reference method for particle-size sampling.

6.2.2.4 Method of Analysis

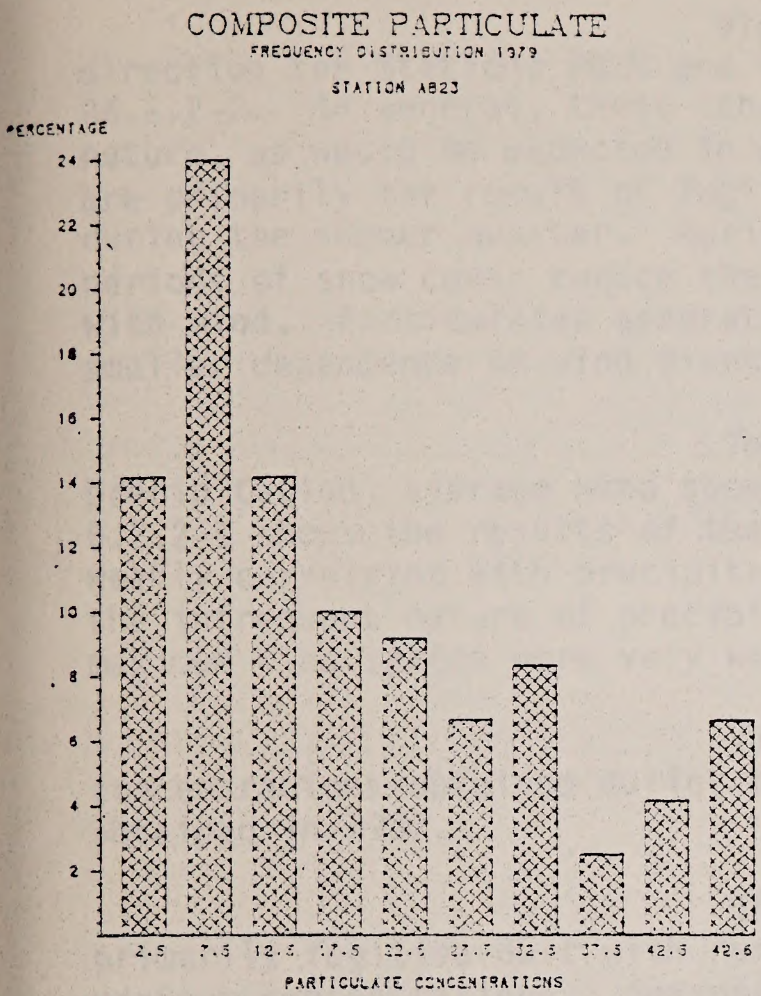
Methods used in analyzing particulate data were multiple regression analyses using a set of meteorological parameters and qualitative examination of time series plots.

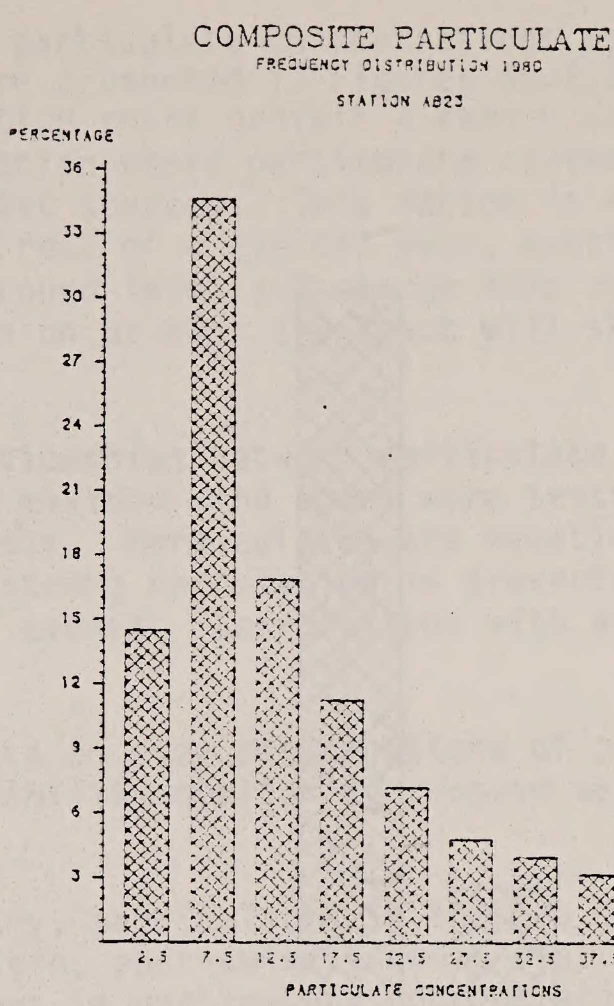
6.2.2.5 Discussion and Results

The time-series plot of particulate concentrations for Station AB23 and Table 6.2.1-3 are used for this discussion. One dominant feature of the plot is the seasonal variability. Maximum concentration levels typically occur in the late spring with minimum levels in the winter. Concentrations during the late summer months are variable, but are generally lower than the spring peaks. Monthly averages, on the other hand, peak in the summer months.

Histograms depicting the frequency distributions of particulate concentrations (Figures 6.2.2-1 and 6.2.2-2) show the predominance of concentrations less than 20 to 25 ug/m^3. The composite histogram also displays a skewed log-normal distribution, typical of particulate concentrations that are influenced by random variation in meteorological parameters.

Table 6.2.1-6, shown previously, lists the maximum annual and 24-hour particulate concentrations over the past three years. The Federal Primary Standards have not been exceeded at any time. On a 24-hour basis, over the past three years the maximum value reached was 100 ug/m^3 compared to the standard of 260. A wider margin exists on an annual basis. The Federal Secondary Annual Standard of 60 ug/m^3 is not approached.





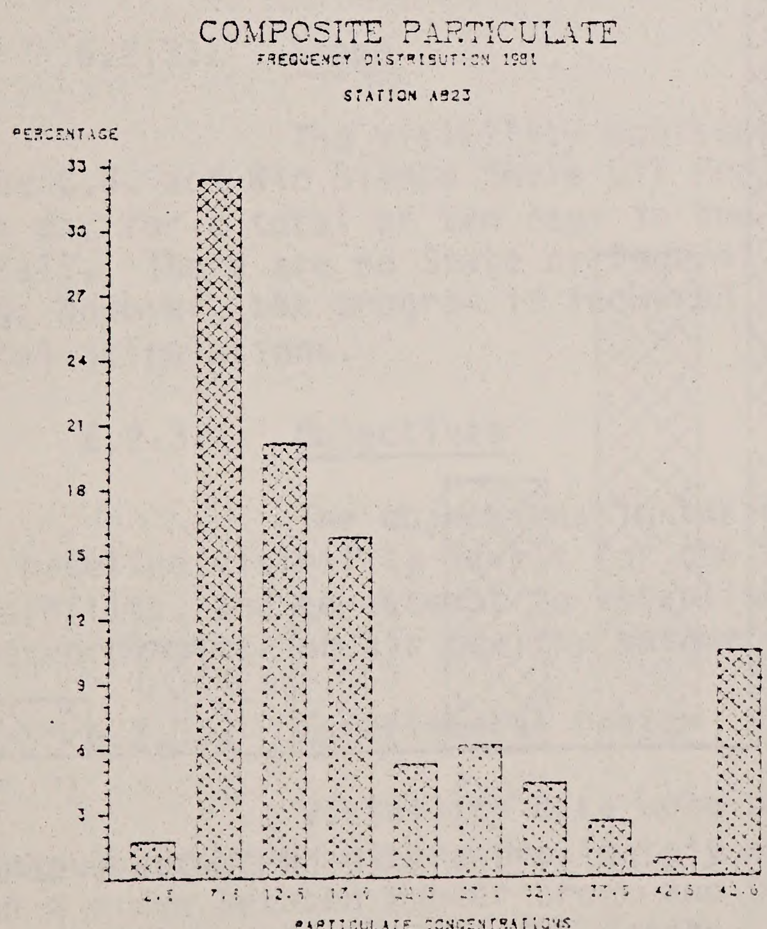


Figure 6.2.2-1
Composite Frequency Distributions of Particulate
Measurements (ug/m^3) by Year, Station AB23

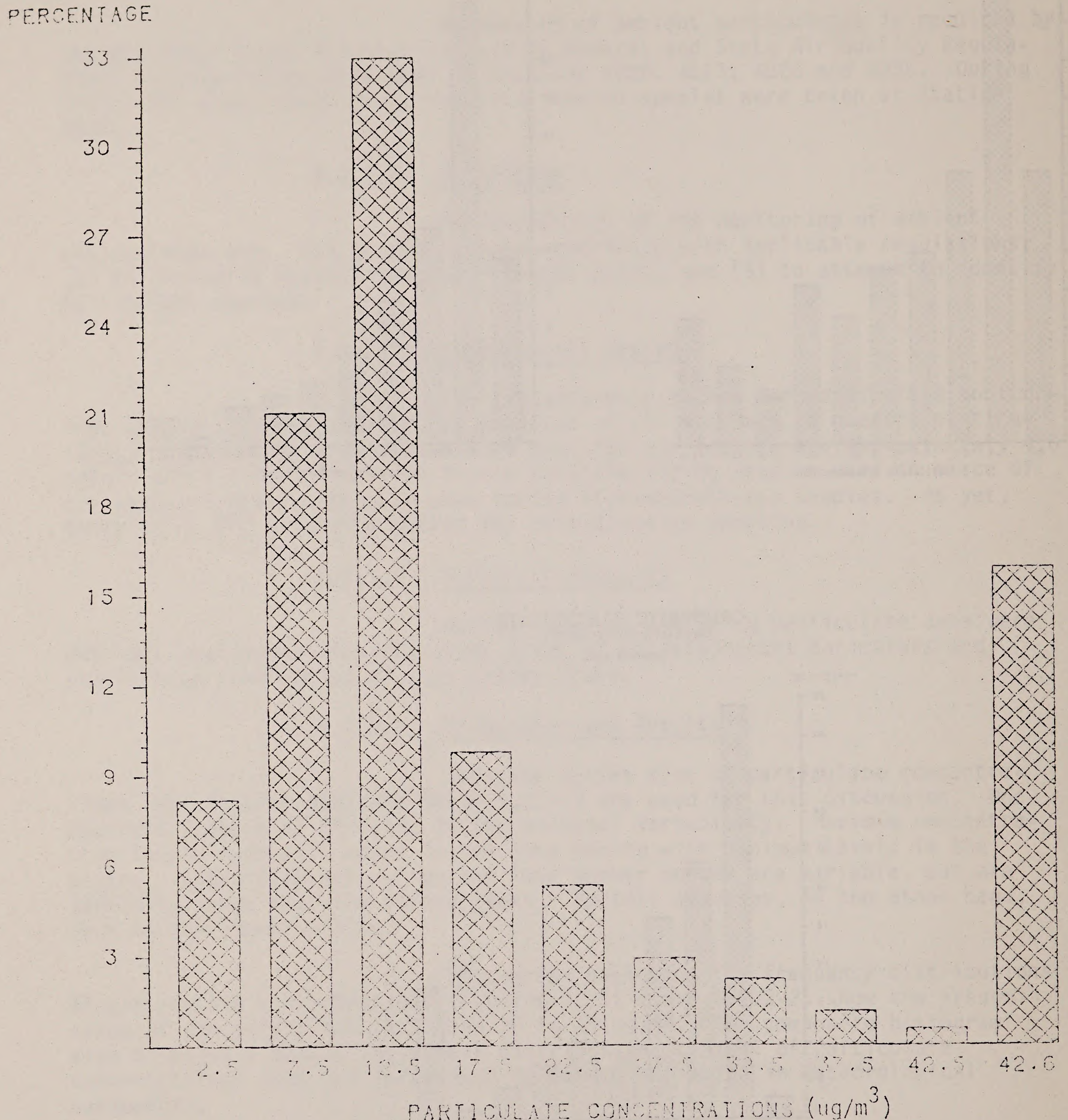


Figure 6.2.2-2
Composite Particulate
Frequency Distribution, 1975-81, Station AB23

Plots of particulate concentrations vs. wind direction for Stations AB20 and AB23 are presented in Figures A6.2.2-1 and A6.2.2-2. In general, these concentration roses exhibit a random directional nature, as would be expected in a situation where particulate concentrations are primarily the result of fugitive dust sources. This factor is most evident during the summer quarter. During the rest of a typical year, substantial periods of snow cover reduce the background level and change this relationship with wind. Particulates generated then on or near the Tract will show a much smaller dependence on wind direction.

The relationships between particulate loading and precipitation, average wind speed, and maximum wind speed were tested. Table 6.2.2-1 shows the results of the analysis. Particulates are negatively but weakly correlated with precipitation; strong correlation is prevented due to the infrequent nature of precipitation events. Correlations with average and maximum wind speeds were very weak.

Valid data on size distributions of particulate concentrations obtained during the visibility monitoring program were not obtained in 1981.

In summary, particulates in the C-b vicinity are primarily fugitive dust with rural origin, particularly those responsible for maximum concentrations. Seasonal trends in particulate concentrations suggest a general dependence on meteorological parameters. No long-term trends are evident in particulate data.

6.2.3 Visibility

6.2.3.1 Scope

The visibility monitoring program has been cosponsored by the C.B. and Rio Blanco Shale Oil Projects. Measurements were taken every sixth day for a total of ten days in the spring quarter, 1981, and ten days in the fall. There are no State or Federal requirements for visibility monitoring; however, the program is required under the Federal Oil Shale Lease Environmental Stipulations.

6.2.3.2 Objectives

The objectives in taking visibility measurements are to establish baseline visibility levels for the Piceance Basin, to identify any trends in visibility, and to attempt to establish correlations between visibility and meteorological or air quality parameters.

6.2.3.3 Experimental Design

Visibility data were obtained by means of telephotography from an observation site approximately eight miles southwest of Piceance Creek on a ridge between Hunter Creek and Dry Gulch. This site was chosen for its proximity to the C-a and C-b Tracts, as well as for its accessibility and range of views.

TABLE 6.2.2-1

Correlation of Particulate Data with Precipitation,
Average Wind Speed, and Maximum Wind Speed
December 1, 1980-December 1, 1981

	Precipitation	Average Wind Speed	Maximum Wind Speed
Correlation Coefficient, r	-0.402	0.171	0.212
Significance	0.051	0.083	0.031
No. of Observations	24	103*	103

*Particulates are measured every third day.

Photographs are taken at hourly intervals throughout the measurement days in each of four views as shown on Figure 6.2.3-1. The use of at least two objects in each view enabled the measurement of visual range under a variety of visibility conditions. The locations of the observation site and objects are shown on the Figure.

Visual range information is extracted from the photographs by means of optical density measurements on the portions of the photograph representing a given object and the horizon sky directly above it. These densities, together with the actual object-camera distance and the object albedo, are used to calculate a visual range.

6.2.3.4 Method of Analysis

There have been only three years of seasonal visibility measurements since the baseline visibility study of 1975-76; therefore there is no basis for analysis of long-term in visibility. Visual range results have been compiled and averaged for each view and on a composite basis over monthly, seasonal, and annual periods to facilitate comparison with baseline data.

Correlaticn and multiple regression analyses using 1981 visibility data were used to evaluate visual range relationships with a set of meteorological parameters.

6.2.3.5 Discussion and Results

The results of the 1981 visibility monitoring program are summarized in the histogram in the time-series plots, as averaged over all views. The four views are shown in Figure 6.2.3-1. Visual range measurements were variable each month, averaging higher values in the fall. May measurements showed wide variation from 90 km to 165 km. Wide ranges in visibility during May and October were associated with synoptic weather patterns.

Figures 6.2.3-2 and 6.2.3-3 show the variation in visual range for each view. The inherent radiance of each target within the four different views produce variable visual range values on any single measurement time. The effects of view azimuth and solar geometry are taken into account.

Table 6.2.3-1 is a summary of the regression analysis of visual range with respect to particulates, relative humidity, and wind speed. The most highly correlated variable for each view is listed along with the corresponding value of r^2. All correlations are weak in that at the 5% level of significance no correlation exists.

Multiple stepwise regression analysis of the 1981 visual range data showed that no reliable model for prediction could be found.

Average visual range for spring 1981 was 82 miles, an increase of 4 miles from 1980. For the years 1976-1979, average spring visual range was 72 miles. During Fall 1981, mean visual range was 88 miles, an increase of 3 miles from 1980. For previous years 1976-1979, the

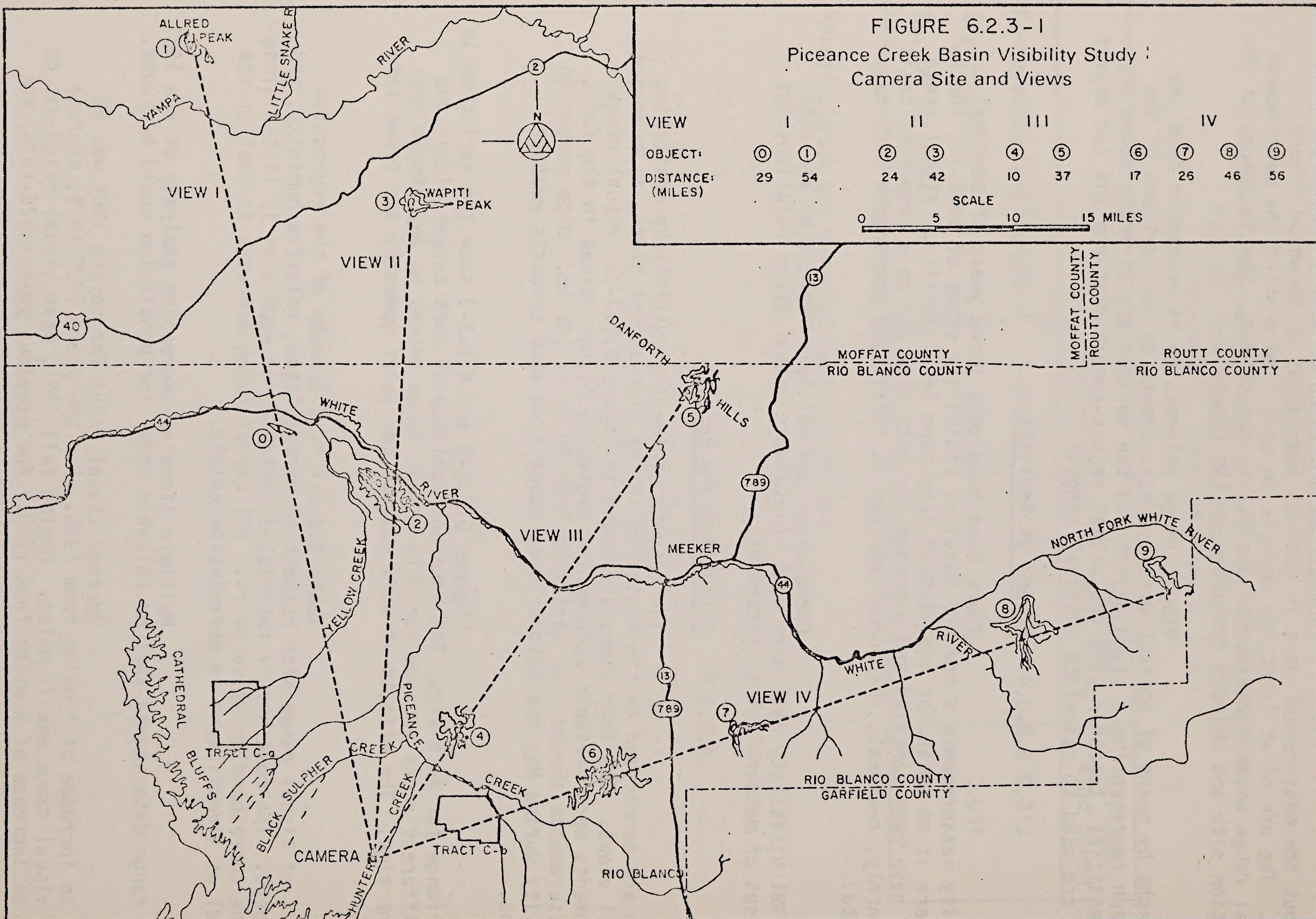


FIGURE 6.2.3-1
Piceance Creek Basin Visibility Study: Camera Site and Views

Figure 6.2.3-2

Variation in Daily Mean Visual Range by View, Spring 1981

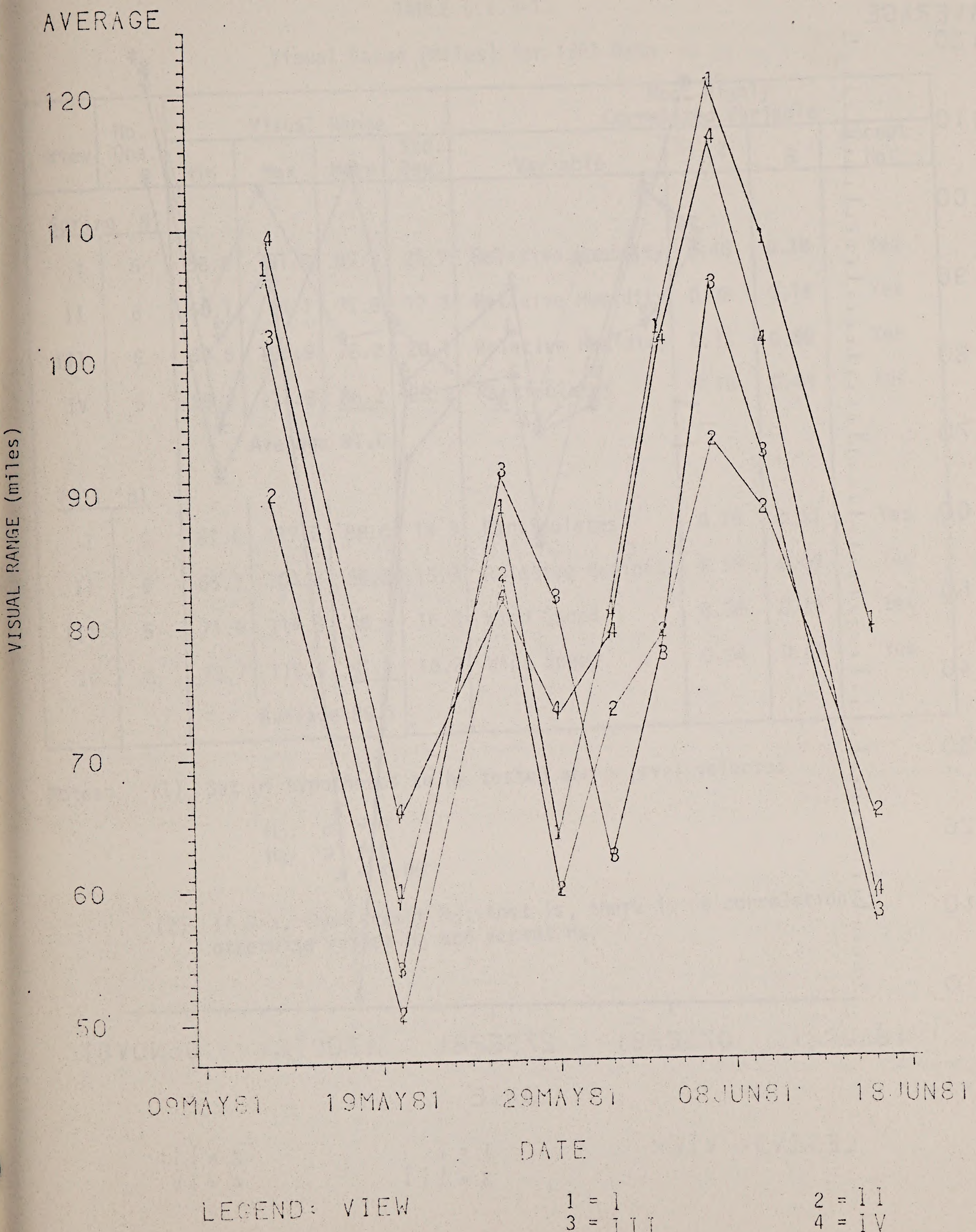


Figure 6.2.3-3

Variation in Daily Mean Visual Range by View, Fall 1981

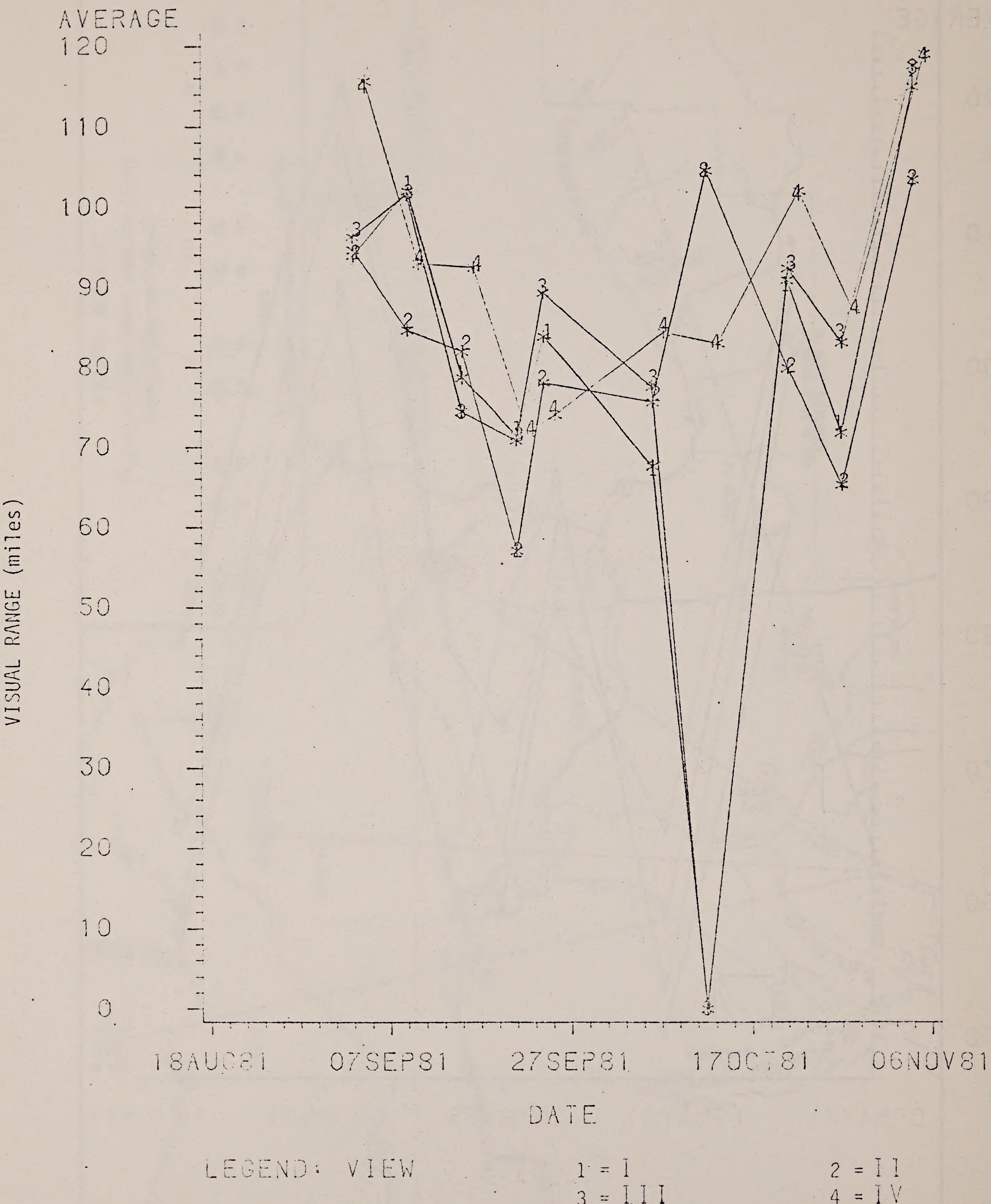


TABLE 6.2.3-1

Visual Range (Miles) for 1981 Data

View	No. Obs.	Visual Range Min	Max	Mean	Std. Dev.	Most Highly Correlated Variable: Variable	r^2	$\hat{\alpha}$	Accept H_0:
Spring '81									
I	6	58.8	121.3	89.3	25.7	Relative Humidity	0.40	0.18	Yes
II	6	50.1	94.1	72.8	17.3	Relative Humidity	0.38	0.19	Yes
III	6	53.6	105.9	78.2	20.1	Relative Humidity	0.12	0.50	Yes
IV	6	59.2	116.8	86.2	23.3	Particulates	0.16	0.43	Yes
				Average 81.6					
Fall '81									
I	5	67.4	117.2	88.6	18.3	Particulates	0.16	0.51	Yes
II	6	65.1	104.2	84.2	15.8	Relative Humidity	0.55	0.09	Yes
III	5	71.5	114.5	88.6	16.5	Wind Speed	0.38	0.26	Yes
IV	6	73.7	118.5	91.1	16.2	Wind Speed	0.04	0.69	Yes
				Average 88.1					

Notes: (1) Set of hypotheses to be tested and α level selected

$$H_0: \rho^2 = 0$$
$$H_a: \rho^2 \neq 0$$
$$\alpha = 0.05$$

(2) If $\hat{\alpha}>\alpha$, then accept H_0; that is, there is no correlation, otherwise reject H_0 and accept H_a.

mean visual range for fall measurements was 82 miles, showing that the fall visual range appeared better than the previous years. No time trends in visual range are apparent based on presently available data.

6.3 Meteorology

6.3.1 Climatological Records

6.3.1.1 Scope

The climatological parameters include temperature, solar radiation, precipitation, evaporation, relative humidity, and barometric pressure. These records primarily serve as a historical data base to assess climatological effects principally on the biotic portion of the ecosystem so they may subsequently be sorted from potential man-induced effects.

6.3.1.2 Objectives

Objectives are to establish this historical data base to determine any cyclical or long-term trends that might exist as well as averages and extremes, as appropriate.

6.3.1.3 Experimental Design

The climatological network is shown on Figures 6.3.1-1a and 6.3.1-1b. Parameters measured, instrumentation used, sampling stations and minimum reporting frequency are presented in Table 6.3.1-1.

6.3.1.4 Method of Analysis

Table 6.3.1-2 presents a summary of data formats and analysis along with station identification. Data presentation and analysis techniques include histograms, plots, and tables for all variables. Time-series plots for all Class I indicator variables are in the time-series Supplements to the Development Monitoring (data) Reports.

6.3.1.5 Discussion and Results

6.3.1.5.1. Temperature

Annual mean temperatures at the Tract (Station AB23) have averaged between 6 and 9°C over the past six years.

Between-station comparisons (Stations AB20 vs. AB23) indicate minimum temperatures up to 22°C cooler in Piceance Valley than on Tract due principally to cold air drainage associated with katabatic winds, with valley temperatures reaching extremes of -43°C since baseline. Minimum, average and maximum temperatures for periods 1975 through 1981 are shown in Table A6.3.1-1.

Growing season length data are presented on Table A6.3.1-2. Growing seasons over the past six years have varied from 111 days in 1976 to 157 days in 1981.

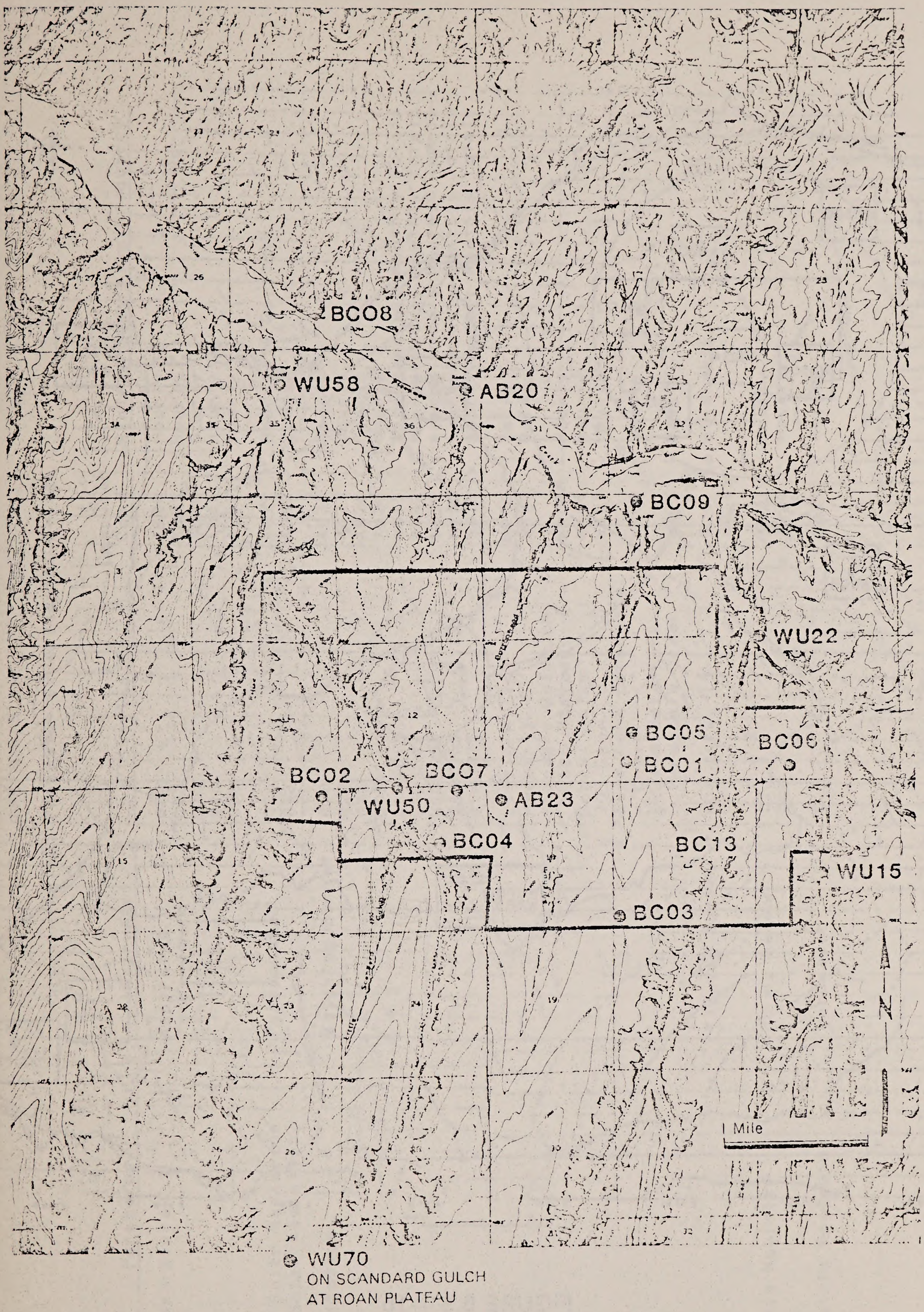


FIGURE 6.3.1-1a
CLIMATOLOGICAL NETWORK NEAR TRACT

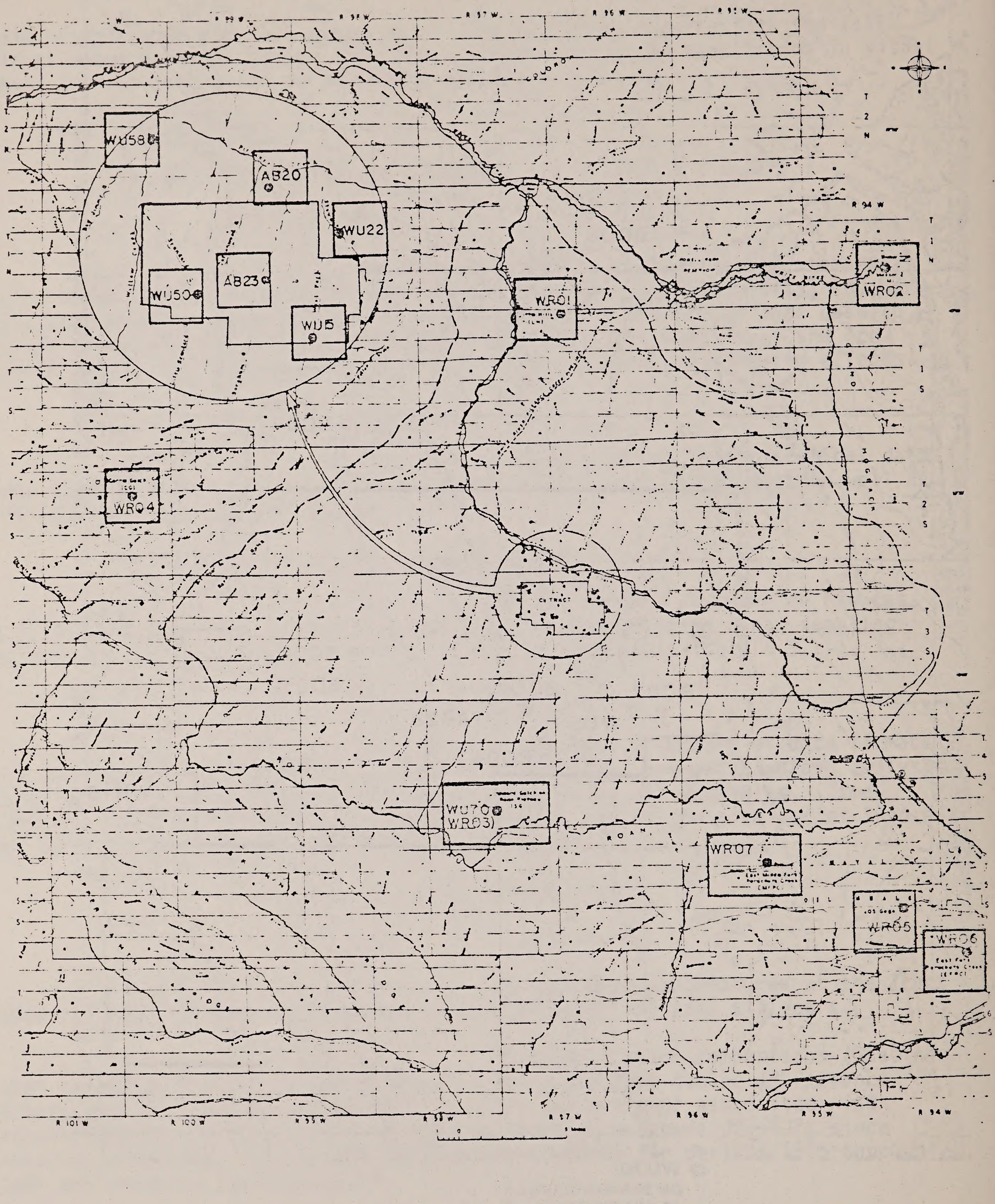


FIGURE 6.3.1-1b
CLIMATOLOGICAL NETWORK OFF-TRACT

TABLE 6.3.1-1

Climatological Parameter Experimental Design

Parameter	Instrument	Station(s)	Computer Code	Minimum Reporting Frequency
Air Temperature	Aspirated Temperature Sensor	020	AB20	Hourly
		023	AB23	Hourly
		026	AB26	Hourly
		042	AD42	Hourly
		056	AD56	Hourly
Direct Solar Radiation	Pyranometer	023	AB23	Hourly in Daylight
Total Solar Radiation		042	AD42	Hourly
Precipitation	Weighing Bucket	020	AB20	Hourly
		023	AB23	Hourly
		026	AB26	Hourly
		028	AD28	Hourly
		USGS015	WU15	Approximately Monthly Totals
		USGS022	WU22	Approximately Monthly Totals
		USGS050	WU50	Approximately Monthly Totals
		USGS058	WU58	Approximately Monthly Totals
		USGS070	WU70	Approximately Monthly Totals
		Little Hills	WR01	Daily
		Meeker 2	WR02	Daily
		Scandard Gulch on Roan Plateau	WR03	Hourly
		Corral Gulch	WR04	Hourly
		JQS Gage	WR05	Hourly
		East Fork Parachute Creek	WR06	Hourly
		East Middle Fork Parachute Creek	WR07	Hourly
	Tipping Bucket	MC1 to 9, 13	BC01 to 09, 13	Bi-Weekly
Relative Humidity	R. H. Sensor	023	AB23	Hourly
		026	AB26	Hourly
Barometric Pressure	Barometer	023	AB23	Hourly

TABLE 6.3.1-2

Climatological Data Summary

Variable	Item	Station	Type Presentation/Analysis	Figure Table Number
Air Temperature	Daily Mean, Minimum Maximum	AB20, 23 AD42, 56	Time Series Plots	*Section 4.2.3 *Section 4.2.3
	Monthly Values of Hourly Maximum, Mean, Minimum	AB20, 23	Tabular	Table A6.3.1-1
Direct Solar Radiation	Daily Total	AB23	Time Series Plots	*Section 4.2.3
	Daily Mean, Maximum and Minimum for Month	AB23	Tabular	Table A6.3.1-3
Relative Humidity	Daily Mean, Minimum, Maximum	AB23	Time Series Plots	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean and Minimum	AB23	Tabular	Table A6.3.1-4
Precipitation	Daily Total	AB20, 23	Time Series Plots	*Section 4.2.3
	Monthly Total	AB20, 23 WU15, 22 WU50, 58 WU70 BC01-09, BC13 WR01-07	Tabular	Table A6.3.1-5
	Between Station Comparison	AB20, 23 WU70, WR01 BC02-05 BC07-09	Regession Analysis	Table 6.3.1-3
	Regional	National Weather	Isohyet	Figure 6.3.1-2
Barometric Pressure	Daily Mean, Minimum, Maximum	AB23	Time Series Plot	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean & Minimum	AB23	Tabular	Table A6.3.1-6

*Supplements to the Development Monitoring (Data) Reports

6.3.1.5.2 Solar Radiation

Direct solar radiation, as measured by a pyranometer, historically varies from a monthly average of 658 langleys per day in June near summer solstice to approximately 117 langleys in December near winter solstice; the 1981 data were similar to those of previous years. This variation approximates the yearly cycle in the daily peaks in the cosine of the sun's zenith angle. Values are presented in Table A6.3.1-3.

6.3.1.5.3 Relative Humidity

Annual means of relative humidity at the Tract, (Station AB23) have averaged between 53 percent and 56 percent over the past five years, with summer minimums as low as seven percent (Table A6.3.1-4).

6.3.1.5.4 Precipitation

Precipitation data, as indicated on Figures 6.3.1-1a and -1b and Table 6.3.1-1 include measurements near two air quality stations, four U.S.G.S. stream gauging stations, one U.S.G.S. station on the Roan Plateau, ten microclimate stations, and seven additional stations as required by the Water Augmentation Plan. Monthly totals for 1981 over all stations are presented in Table A6.3.1-5. Monthly averages at the U.S.G.S. stations are approximate only, inasmuch as sampling of these stations is randomized. Annual totals for 1981 cannot be presented because of instrument malfunction at both AB20 and AB23 in November. Regression analysis was performed among selected precipitation monitoring stations in order to determine potential correlations. The results are summarized on Table 6.3.1-3. The correlation is good between Stations AB20 and AB23 which utilize identical sampling techniques. Stations exhibiting low correlations underscore the local nature of precipitation events.

Regional precipitation patterns have demonstrated that they are influenced by the local terrain and difference in elevation between plateau and river valley with the elevated areas usually receiving more precipitation than the valleys. Isohyets for 1980 are presented in Figure 6.3.1-2. The highest yearly-average total-precipitation area in the region is usually located near the Marvine Ranch station (elevation 7,800 feet) which receives its major precipitation in the winter and spring in the form of snow.

6.3.1.5.5 Evaporation

Evaporation data were not collected in 1981.

6.3.1.5.6 Barometric Pressure

Annual mean barometric pressures at Tract Station AB23 have averaged 787 mb over the past five years. In 1981 daily average minimums were as low as 748, and maximums as high as 801 mb (Table A6.3.1-6).

TABLE 6.3.1-3

Monthly Precipitation Regression

$$y = a + bx$$

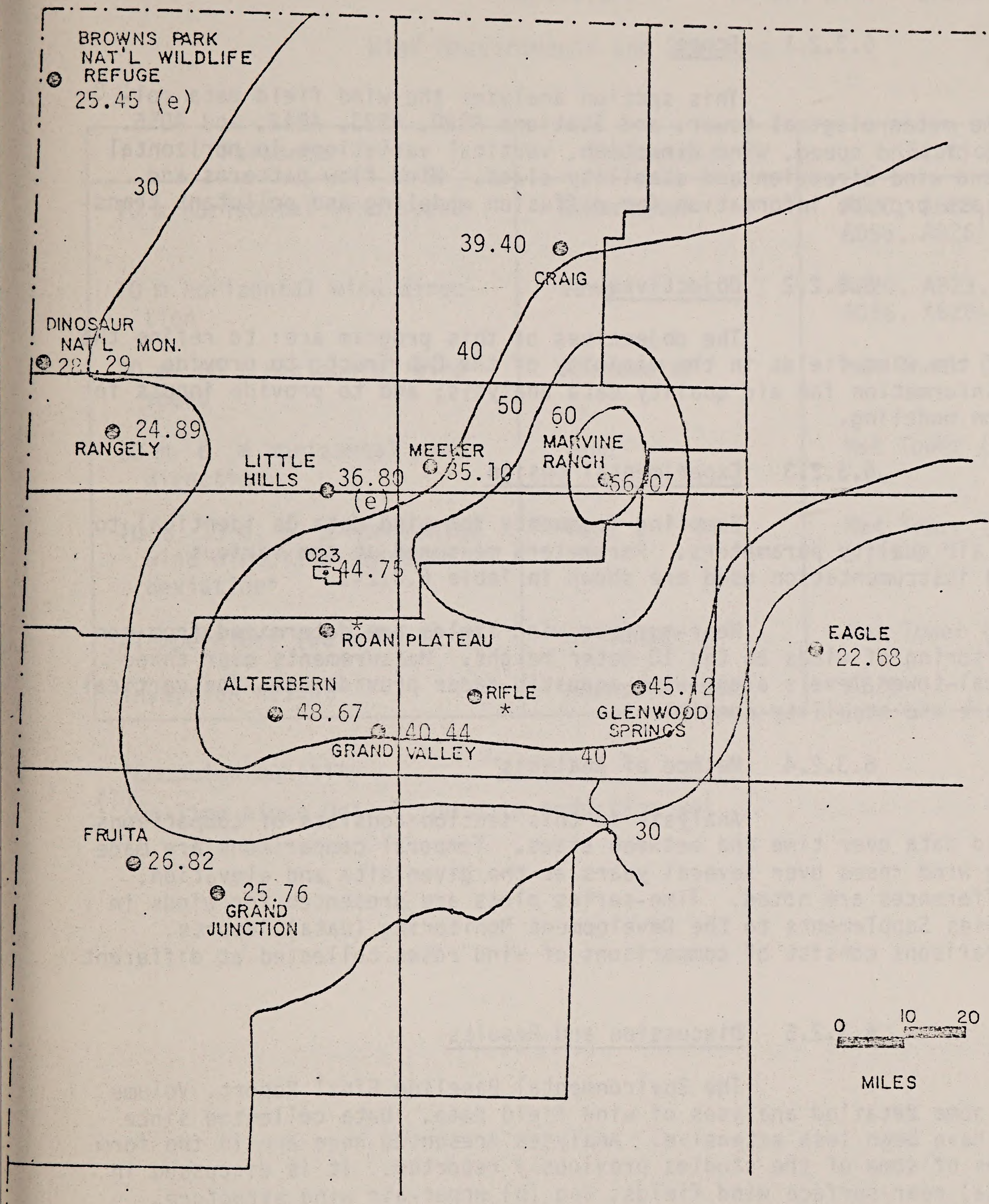
Station (y)	Station (x)	n*	a	b	r^2 Coefficient of Correlation
AB23	AB20	12	0.26	0.72	0.84
WR01(1)	AB20	9	0.04	1.23	0.75
WR01	AB23	9	0.03	1.24	0.47
BC02(7)	AB23	9	-0.25	1.14	0.83
BC03(8)	AB23	9	-0.19	1.04	0.77
BC04(2)	AB23	9	-0.46	1.37	0.91
BC05(3)	AB23	9	-0.25	0.77	0.77
BC07(4)	AB23	9	-0.35	1.14	0.80
BC08(5)	AB20	9	0.51	0.14	0.66
BC09(6)	AB20	8	0.38	0.09	0.03

*Number of samples in regression

(1) Little Hills Station about 12 miles north of the Tract.
(2) Located about 1/2 mile southeast of AB23.
(3) Located about 1 mile northeast of AB23.
(4) Located about 1/4 mile west of AB23.
(5) Located about 1 mile downstream of AB20 in Piceance Creek.
(6) Located about 1-1/2 mile upstream of AB20 in Piceance Creek
(7) Located about 1-1/4 mile west of AB23.
(8) Located about 1-1/4 mile southeast of AB23.

Figure 6.3.1-2

Regional Precipitation Pattern for 1980



*No Data Available

(e) = Estimated Value

6.3.2 Wind Fields

6.3.2.1 Scope

This section analyzes the wind field data collected at the meteorological tower, and Stations AB20, AB23, AD42, and AD56. Data consist of wind speed, wind direction, vertical variations in horizontal wind speed and wind direction and stability class. Wind flow patterns and stability class provide information for diffusion modeling and pollutant transport.

6.3.2.2 Objectives

The objectives of this program are: to refine the knowledge of the wind fields in the vicinity of the C-b Tract; to provide supporting information for air quality data analysis; and to provide inputs for air diffusion modeling.

6.3.2.3 Experimental Design

Sampling frequency for wind data is identical to that of the air quality parameters. Parameters measured at the various stations and instrumentation used are shown in Table 6.3.2-1.

Near-surface wind fields are determined from continuous monitoring of winds at the 10 meter height. Measurements over three meteorological-tower levels along with acoustic radar provide data for vertical wind structure and stability conditions.

6.3.2.4 Method of Analysis

Analysis in this section consists of comparisons of wind field data over time and between sites. Temporal comparisons are made by comparing wind roses over several years at the given site and elevation. Seasonal differences are noted. Time-series plots are presented for winds in the Time-Series Supplements to the Development Monitoring (data) Reports. Spatial comparisons consist of comparisons of wind roses collected at different sites.

6.3.2.5 Discussion and Results

The Environmental Baseline Final Report, Volume 3, presents some detailed analyses of wind field data. Data collected since that report have been less extensive. Analyses presented here are in the form of extensions of some of the studies previously reported. It is discussed in two parts: (a) near-surface wind fields, and (b) upper-air wind structure.

6.3.2.5.1 Near-Surface Wind Fields

Determination of predominant wind speed and wind direction can be made by examination of quarterly wind roses over the seasons and from year to year. Figures A6.3.2-1 through A6.3.2-16 present the quarterly and annual wind rose plots for two years for the various meteorological stations. Typical quarterly and annual roses are shown on

TABLE 6.3.2-1

Wind Measurements and Stations

Parameter	Instrument	Station
10 m Horizontal wind speed	Anemometer	AB20, AB23, AD42, AD56, AB26(1)
10 m Horizontal wind direction	Vane	AB20, AB23, AD42, AD56, AB26(1)
30 m 60 m Horizontal wind speed	Anemometer	Met Tower (AA23)
30 m 6 m Horizontal wind direction	Vane	Met Tower (AA23)
10 m, 30 m, 60 m Horizontal wind direction standard deviation*	Vane	Met Tower (AA23)
ΔTemperature (60 m to 10 m)	ΔT Sensor	Met Tower (AA23)
Inversion height	Acoustic radar	AB20

*Computed quantity

(1)On-line since Oct. 1; no data reduction yet

Figures 6.3.2-1 and 6.3.2-2 for the 10 meter level of the meteorological tower. The predominant wind direction at the meteorological tower is SSW. The winter quarter of 1981 exhibited a stronger easterly component then normal at both the 30 meter and 60 meter levels. Fall and winter quarters have lower wind speeds than spring and summer at the 10 meter level. However, at the 30 meter level the wind speed difference between seasonal quarters is less. As expected, wind speeds at 60 meter level are higher than at the two lower levels.

Stations located in or near Piceance Creek Valley (AB20, AD42, AD56) tend to show downstream (drainage) flow at night (E-ESE) and upstream flow (W-WNW) in daytime for all seasons with drainage predominant.

6.3.2.5.2 Upper-Air Wind Structure

Two analyses are presented in this section: (a) acoustic radar inversion and mixing data, and (b) atmospheric stability.

(a) Inversion and Mixing Heights. Temperature inversion heights are measure by means of an AeroVironment Model 300 Acoustic Radar. The instrument was reactivated at Piceance Creek Station AB20 in November, 1977. The output of the instrument is a continuous strip chart record of reflected sound signals associated with thermal signatures; such signatures vary in character depending on whether the atmosphere is stable or unstable. The chart provides a means for determining the height of temperature inversions and mixing layers above ground level.

Figure A6.3.2-17 shows average monthly inversion heights for months of December, 1980 through November, 1981. The months are grouped by quarters to show seasonal patterns. Plots have been limited to hours with expectation of occurrence greater than 0.5. Maximum inversion heights were in the following ranges (meters):

Winter Quarter	350-425
Spring Quarter	325-475
Summer Quarter	430-470
Fall Quarter	260-330

Inversions are diurnal and approximately the same average duration as in previous years.

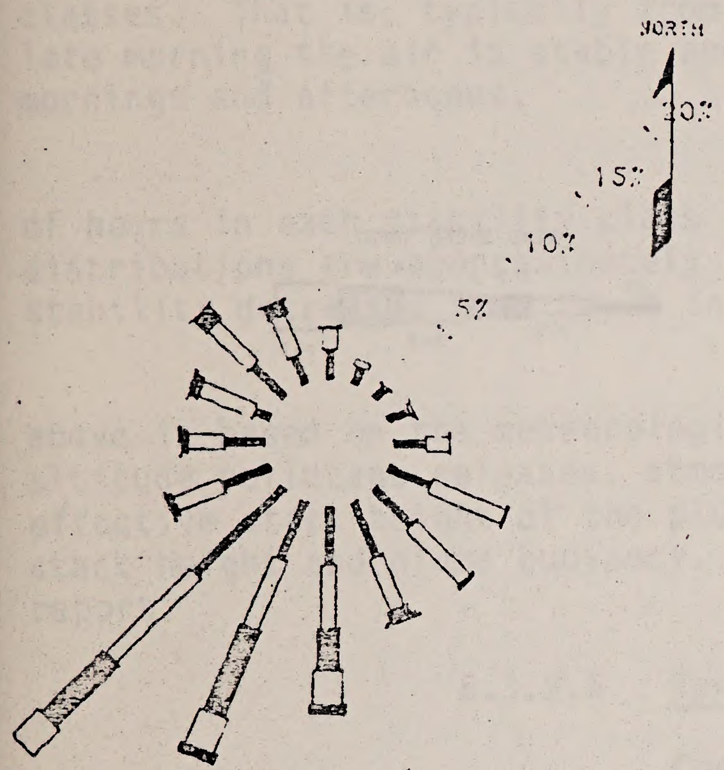
For inversions aloft, the air layer between the mixing height and the top of the inversion is stable and very little diffusion of stack emissions occurs in this air layer. Any stack emissions below the mixing height are constrained by the inversion when thermal buoyancy of the plume is not great; otherwise this layer can be penetrated. Stack emissions above the inversion height will not penetrate down through the inversion. No new afternoon mixing height data were generated in 1981.

(b) Stability Class Study. Monthly average stability classes have been derived from hourly stability class data. The hourly stability classes are based on delta temperature measurements from the 60-meter to the 10-meter levels on the meteorological tower. Pasquill-

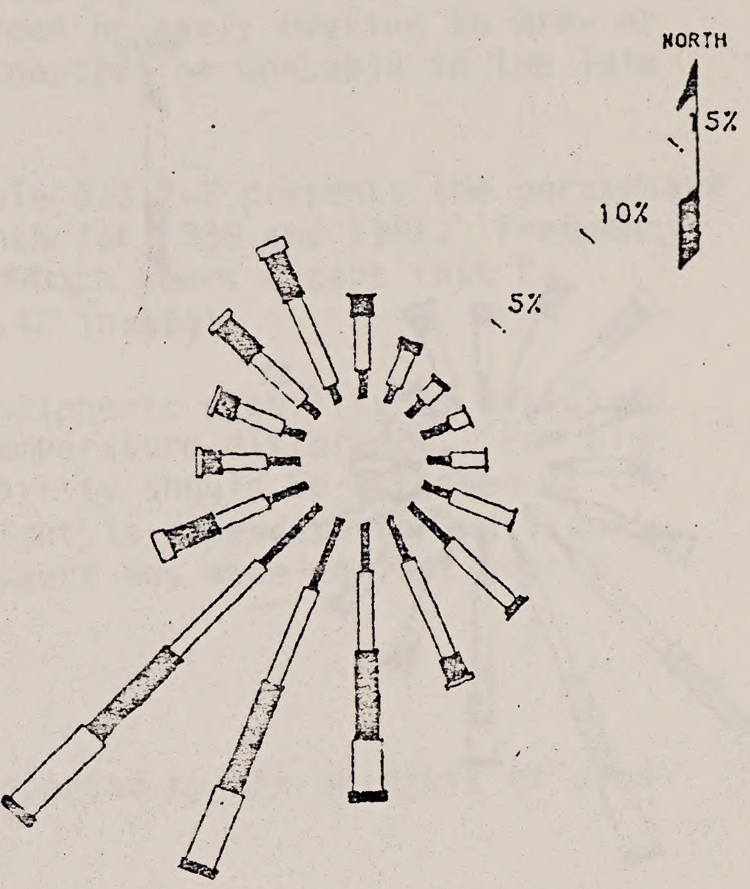
Figure 6.3.2-1

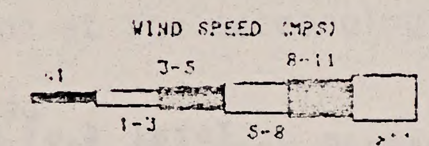
AA23 QUARTERLY WIND ROSE @ 10M

DEC '80 - FEB '81
Total % of Calms Distributed (0.33%)
Total No. of 1-Hour Samples - 2092

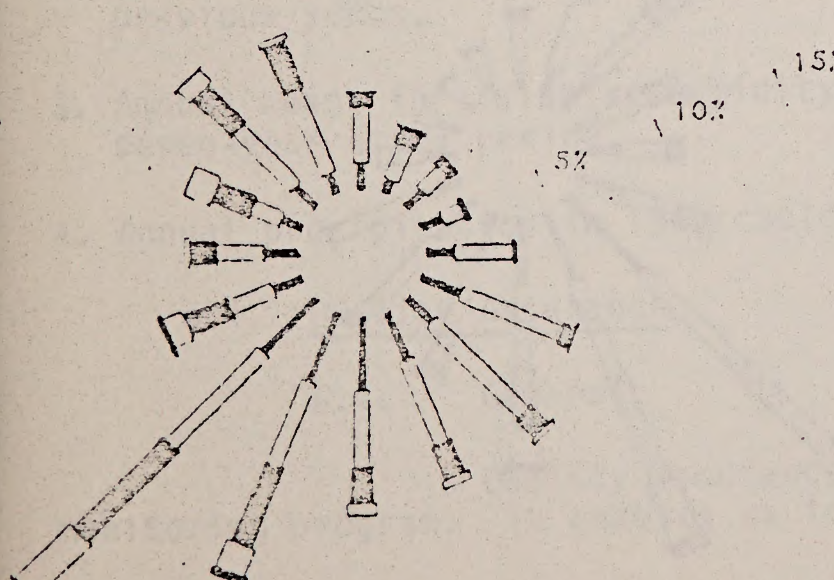


MAR '81 - MAY '81
Total % of Calms Distributed (0.0%)
Total No. of 1-Hour Samples - 2110

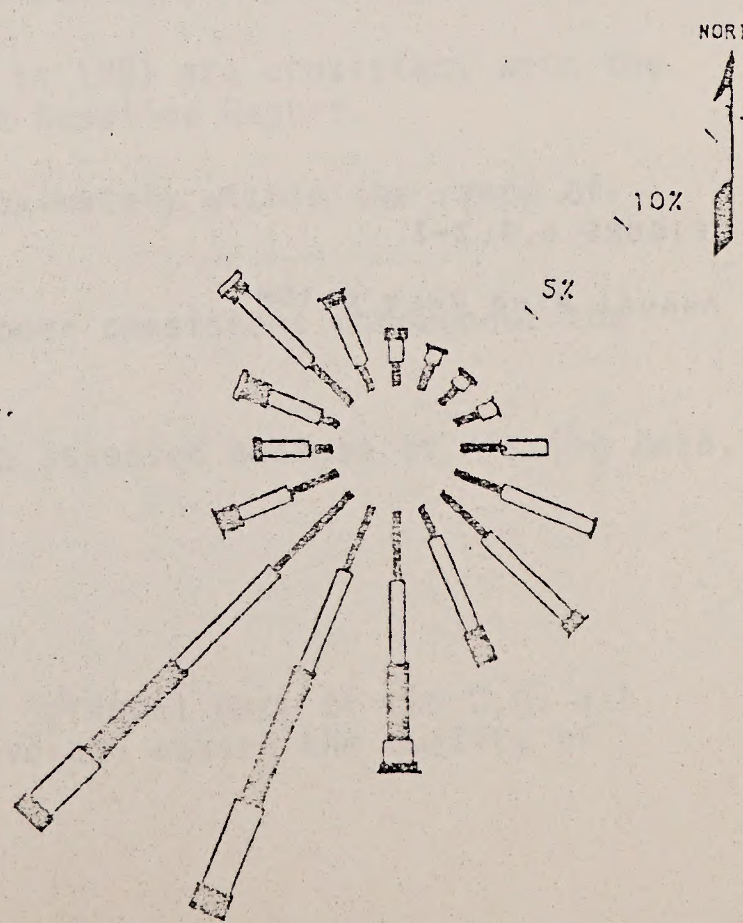




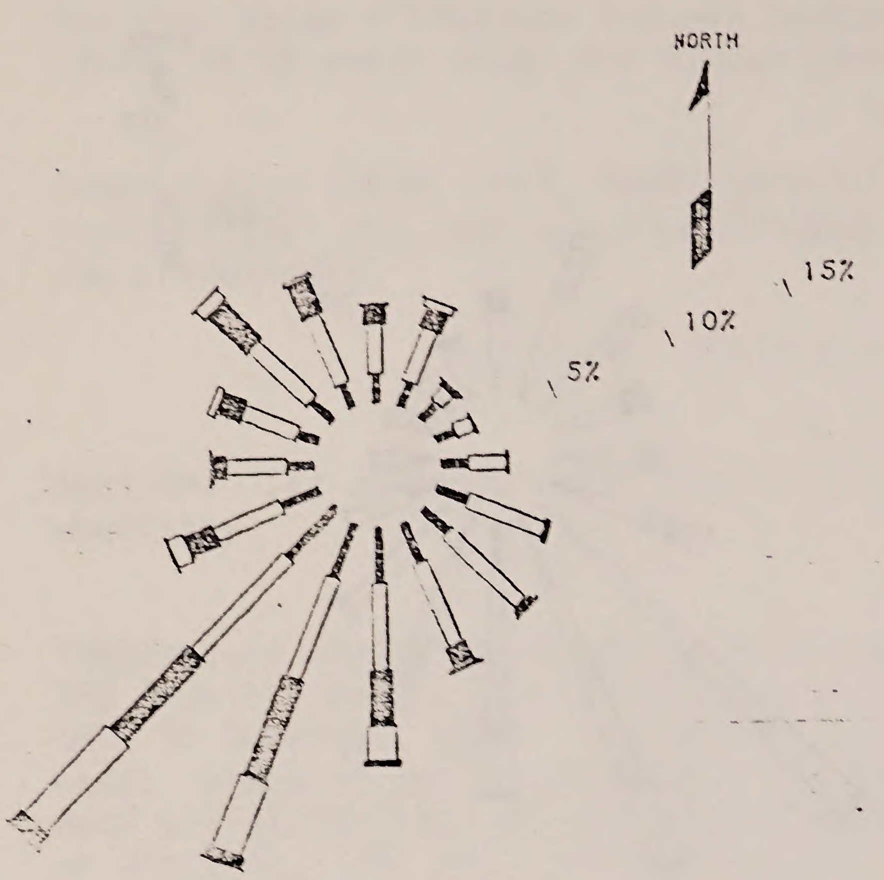
JUN '81 - AUG '81
Total % of Calms Distributed (0.0%)
Total No. of 1-Hour Samples - 1942

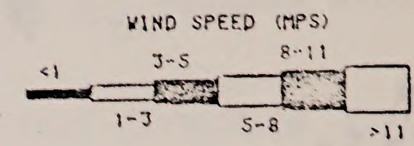


SEP '81 - NOV '81
Total % of Calms Distributed (0.0%)
Total No. of 1-Hour Samples - 2087



DEC '79 - NOV '80
Total % of Calms Distributed (0.01 %)
Total No. of 1-Hour Samples - 8486





DEC '80 - NOV '81
Total % of Calms Distributed (0.09%)
Total No. of 1-Hour Samples - 8231

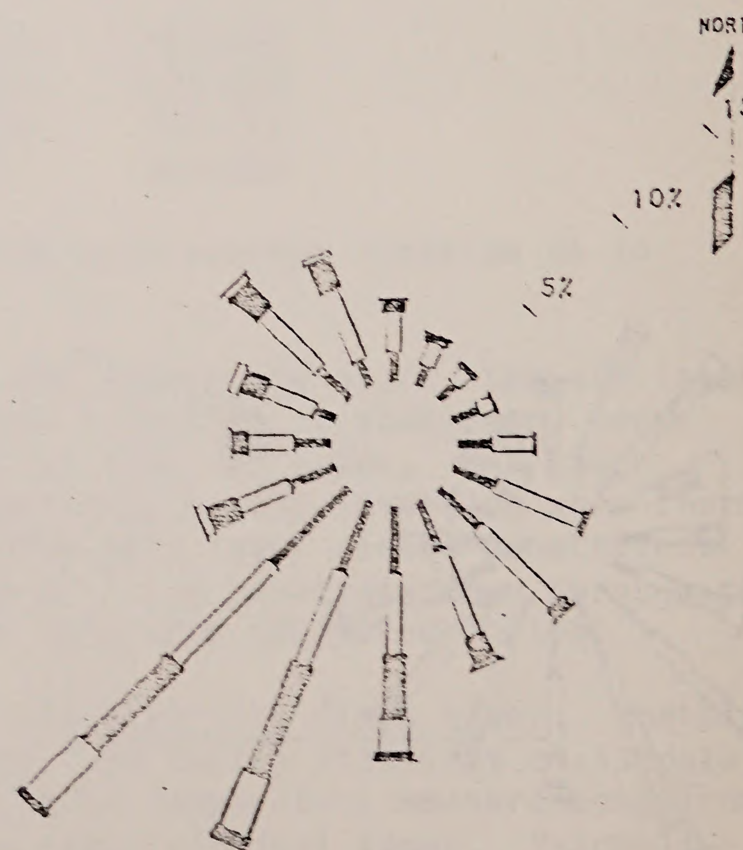


FIGURE 6.3.2-2

AA23 Annual Wind Rose @ 10M

Gifford stability classes were determined from the slope of the temperature-altitude curve (dT/dz) and adjusted for wind speed by the method described in the Baseline Report, Volume 3. Monthly averages by hour for 1981 are shown in the most recent data report for the months containing more than 50 percent of the data. Comparison of these data with the previous year shows similar patterns for the broad classifications of unstable, neutral, and stable classes. That is, typically from late afternoon or early evening to mid- or late morning the air is stable and shifts to neutral or unstable in the late mornings and afternoons.

Table 6.3.2-2 presents the percentage of hours in each stability class for each month for 1980 and 1981. Frequency distributions are apoproximately the same for both years except that F stability decreased from 24.3% in 1980 to 19.4% in 1981.

Atmospheric stability as discussed above is based on the meteorological-tower temperature difference. For high altitude pollutant releases, atmospheric stability should be assessed at the effective stack height of the plume; this height is dependent on individual stack height and plume buoyancy. This assessment was made in last year's report.

6.3.2.6 Conclusions

Conclusions supported by the analysis of wind-field data are:

1. Predominant wind direction at the meteorological tower site on Tract is SSW.

2. Predominant wind direction in and near Piceance Creek is downstream (from east and southeast) over most of the nighttime and early morning. Daytime direction reverses to upstream flow.

Conclusions supported by analyses from the addition of 1981 data to previously reported climatological data are:

1. Monthly mean temperatures and variations in 1981 are consistent with the values from the past five years since the Baseline Report.

2. Direct solar radiation for 1981 was approximately within the range of previous years.

3. Annual means for relative humidity have been consistent throughout the seven-year study period.

4. Annual precipitation in 1981 could not be assessed because of missing data.

6.4 Quality Assurance

6.4.1 General

Quality Assurance is an integral part of the C.B. air monitoring program. It enables us to improve and assure the quality of

TABLE 6.3.2-2

Meteorological Summary: Stability Class (1) Frequencies (%)
Source: Met Tower (10m to 60m)

Pasquill-Gifford Stability Class	dT/dz Range for this Stability Class (°C/100m)	1979 Dec.	1980 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Annual Mean
A	<-1.9	.6	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	1.3	1.7	1.4	0.5
B	-1.9 to -1.7	.3	.4	.3	.4	5.4	6.6	9.0	9.8	13.7	11.9	13.7	9.7	6.8
C	-1.7 to -1.5	.1	.3	0.0	.1	4.0	10.1	13.0	10.8	11.4	9.2	9.6	14.8	6.9
D	-1.5 to -0.5	22.5	48.3	28.5	47.3	39.6	42.0	28.9	26.8	27.5	25.8	23.2	26.4	32.2
E	-0.5 to 1.5	37.4	34.0	47.3	39.0	31.0	25.1	22.7	24.0	21.1	23.2	22.3	24.5	29.3
F	>1.5	39.1	17.0	23.9	13.2	20.0	16.2	26.1	28.4	26.3	28.6	29.5	23.2	24.3
TOTAL PERCENTAGE		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range for this Stability Class (°C/100m)	1980 Dec.	1981 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Annual Mean
A	<-1.9	0.3	0.4	0.3	0	0.3	2.4	3.2	1.0	1.8	1.2	0.7	0.4	1.0
B	-1.9 to -1.7	4.1	5.0	8.3	7.0	11.2	6.3	11.4	7.0	8.3	4.5	3.1	3.3	6.5
C	-1.7 to -1.5	8.3	7.4	9.8	10.5	9.4	5.7	6.0	5.0	4.3	8.6	2.8	6.8	6.7
D	-1.5 to -0.5	29.7	27.5	31.7	37.7	35.6	40.3	33.7	34.0	24.2	26.5	43.3	36.3	33.4
E	-0.5 to 1.5	32.9	39.9	30.1	29.8	25.5	33.5	28.6	30.0	34.8	44.5	35.6	30.6	33.0
F	>1.5	24.7	19.8	19.8	15.0	18.0	11.9	17.2	23.0	26.6	19.7	14.5	32.6	19.4
TOTAL PERCENTAGE		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(1) Adjusted for wind speed

measured data in pollutant concentrations and associated meteorology. Quality Assurance guidelines for C.B. are set forth in the "Cathedral Bluffs Air Monitoring Quality Assurance Manual and Standard Operating Procedures". Copies of the document were sent to EPA Region VIII and the Colorado Department of Health for final approval in August, 1981. Quality Assurance measures taken by C.B. personnel include the following:

1. Daily zero and one-point span checks (NBS traceable gases).
2. Biweekly precision checks (NBS traceable gases).
3. Quarterly multipoint calibrations (NBS traceable gases).
4. Quarterly independent audits of all analyzers (NBS traceable gases)
5. Semiannual meteorological audits.
6. Periodic systems audits.
7. Routine maintenance of all equipment.
8. Participation in interagency audit program.
9. Computer-aided statistical analysis of data (includes use of control charts and precision and accurancy calculations).
10. All above steps fully documented.
11. Data reviewed by in-house personnel.
12. Data reviewed by State and Federal agencies.

6.4.2 Audit Results

Air quality audits were conducted in 1981 as follows. In May an independent audit by North American Rockwell was conducted. In late December an audit was initiated by the Quality Assurance section of the Environmental Services Department; this was completed in January and will be reported later.

Results of the May audit are presented on Table 6.4.2-1. The β value is the slope of the audited- vs station-measured concentration. As a goal it is desirous of having β values of 1.0 ± 0.1, which was achieved except for ozone at Station AB23.

A systems audit was conducted by Rockwell in December, 1981. Their conclusions and recommendations are as follows:

"In general, CBSOC has a well-run, well-organized system and has paid attention to most of the important aspects of quality assurance in order to produce ambient data of acceptable quality. Each of the people interviewed was conversant with his respective field. There are, however, problems which should be remedied.

TABLE 6.4.2-1

SUMMARY OF $\beta^{(1)}$ VALUES
FOR MAY AUDIT

Channel	Station	5/4/81
NO	AB20	1.019
	AB23	0.985
NO_x	AB20	0.944
	AB23	0.948
NO_2	AB20	1.025*
	AB23	1.011*
SO_2	AB20	0.901
	AB23	0.919
O_3	AB20	0.925*
	AB23	0.890*
CO	AB20	1.007
	AB23	0.910

*EPA Ozone audit device failed; these are re-audited values on 9/1/81

(1) β is the Slope of the Audited vs. Station-Measured Concentrations

The first and most important is to develop the in-house capability to do the required quarterly quality assurance audits or to obtain an outside contractor. In addition, the biweekly precision checks should be implemented along with semiannual Met QA (Meteorological Quality Assurance). Reporting of precision and accuracy data is required by 40CFR Part 58, Appendix B as part of submitting the data. This should be implemented as soon as possible.

A light box should be purchased for filter inspection.

Correction of the procedures for using the UV photometer for calibration of ozone should be instituted immediately.

Use of control charts and reweighing a percentage of filters should be initiated.

The data validation criteria should be established along with the correct procedures for use of the criteria should be developed.

CBSOC should obtain approval of their quality assurance plan.

In summary, CBSOC possesses qualified personnel, excellent facilities and adequate resources. Implementation of the above will allow the production of documented high quality data."

All of the above items have been implemented with the exception of data validation criteria which is partially being validated via a computerized outlier program; additonal procedures are to be implemented here.

The first and most important is to develop the in-house capability to [illegible] the required quality [illegible] [illegible] to [illegible] contractor. In addition, [illegible] [illegible] mented along with [illegible] [illegible] [illegible]. Reporting of [illegible] and [illegible] [illegible] Appendix B as soon [illegible] [illegible] soon as possible.

A light box should be purchased for [illegible] [illegible].

Correction of the procedures [illegible] [illegible] for the correction of store sample [illegible].

Use of control charts and [illegible] [illegible] should be initiated.

The data collection [illegible] [illegible] along with the contract procedures [illegible] [illegible].

CBSDC should [illegible] approval of [illegible] acceptance plan.

In summary, CBSDC [illegible] [illegible] facilities and adequate [illegible] [illegible] the [illegible] tion of [illegible].

[illegible] [illegible]

exception of data [illegible]

unauthorized [illegible]

7.0 NOISE

7.1 Introduction and Scope

The environmental noise program conducted since baseline is not required under the Lease but was requested by the Oil Shale Supervisor. General background noise levels were sought on the Tract and surrounding vicinity prior to Tract development. Monitoring of those levels was reinitiated in February, 1978 to determine the effects of Tract development on noise levels and has continued through the development period. Two stationary noise monitoring stations located at the northern boundary of the tract are shown in Figure 7.1.1-1.

7.2 Environmental Noise

Occupational noise exposure is treated in Section 7.7 of Volume 1 of this report. Aspects of environmental noise treated here deal with traffic and Tract-generated noise levels.

7.2.1 Traffic Noise

7.2.1.1 Scope

The traffic noise study was originated during baseline. Measurements were made one working day per month for approximately one hour at each of 14 locations over a 14-month period starting in September 1975. Measured noise levels (A weightings) above background at two locations along Piceance Creek Road were always made in the presence of passing vehicles. The noise analysis contained in the Final Baseline Report indicated an average level at a station on Piceance Creek Road near Hunter Creek to be 53 dbA which was exceeded ten percent of the time.

On the basis of low noise levels existing during baseline as indicated in the Final Baseline Report, it was felt that continued discrete measurements were warranted at only two of the original 14 locations. Stations NA02 and NA09 were located to indicate traffic noise levels associated with development. Station NA02 is located on Piceance Creek road at the intersection of the Tract access road. A stationary noise monitoring instrument (NB01) was placed in the same vicinity that traffic noise measurements were taken near the Guard Shack, i.e., Station NB01 replaces Station NA09. Discussion of data sampled is presented in Section 7.2.2 (Tract Noise). This method of monitoring traffic noise levels was discontinued in December, 1980, by approval of the OSO. This report contains data not previously reported in last year's annual report.

7.2.1.2 Objective

The objective of traffic noise level measurement is to measure potential increases in traffic noise levels due to development.

7.2.1.3 Experimental Design

Discrete traffic noise measurements were made one per day per week in the presence of passing vehicles at Stations NA02 and NA09

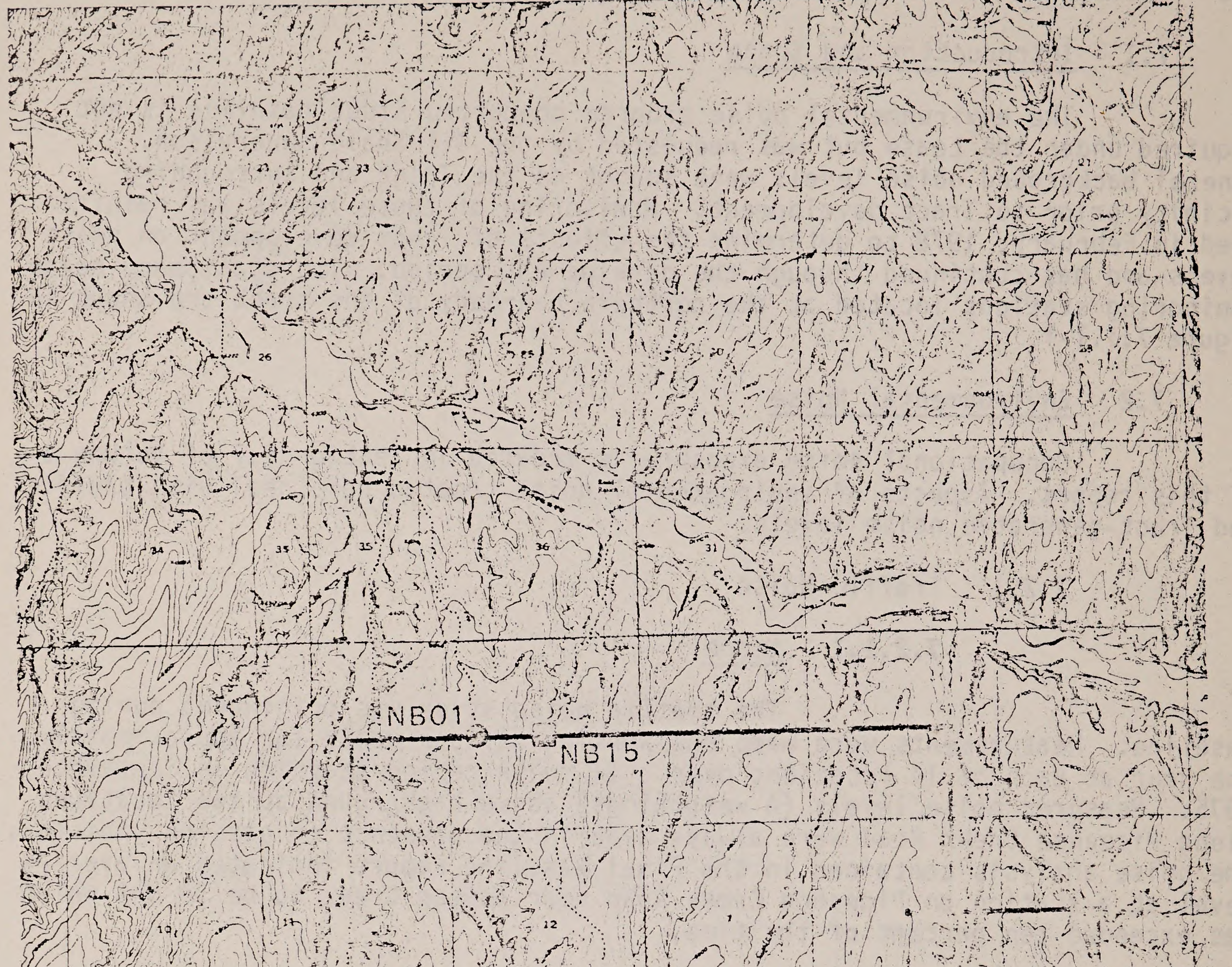


FIGURE 7.1.1-1
NOISE ENVIRONMENTAL MONITORING NETWORK

along Piceance Creek Road and on the access road at the Tract boundary, respectively. The General Radio 1565 Sound Level Meter was used to measure peak noise levels at A weightings. Background levels were obtained the same day at A, B, and C weightings.

7.2.1.4 Method of Analysis

At each of the two stations, peak noise levels were measured weekly. Four weekly composite peak measurements were then averaged.

7.2.1.5 Discussion and Results

Figure 7.2.1-1 shows a time plot of peak traffic noise levels and background levels for the C-b Tract for 1979 and 1980. The highest noise level of 93 dbA occurred in September, 1980. The peak noise level indicated in the Final Baseline Report was 83 dbA in July 1976. The percent of monthly peaks exceeding this level was 15 percent in 1978, 65 percent in 1979, and 67 percent in 1980. On the average, the monthly peaks during the development period remain nine dbA higher than the peaks measured during baseline. The increase is due to developmental activities.

7.2.2 Tract Noise

7.2.2.1 Scope

During the initial phases of development much activity occurs near the northern boundary of the Tract. Thus a noise monitoring stations in the vicinity of operations is most appropriate for monitoring noise levels on the Tract due to early development. An additional noise monitoring station is located near the Guard Shack on the access road to measure traffic and background noise levels attribute to development on the Tract.

7.2.2.2 Objectives

The objectives of the Tract noise study are to evaluate increases in Tract noise due to Tract development, and to demonstrate compliance with State noise regulations.

State noise standards for an industrial zone are as follows in terms of maximum allowable noise levels:

Steady:	80 db(A) 7am to next 7pm
	75 db(A) 7pm to next 7am
15 min. in any one hour:	90 db(A) 7am to next 7pm
Periodic, impulsive, shrill:	75 db(A) 7am to next 7pm
	70 db(A) 7pm to next 7am

These standards apply within 25 feet of the property line. The Tract is not classified industrial at this time.

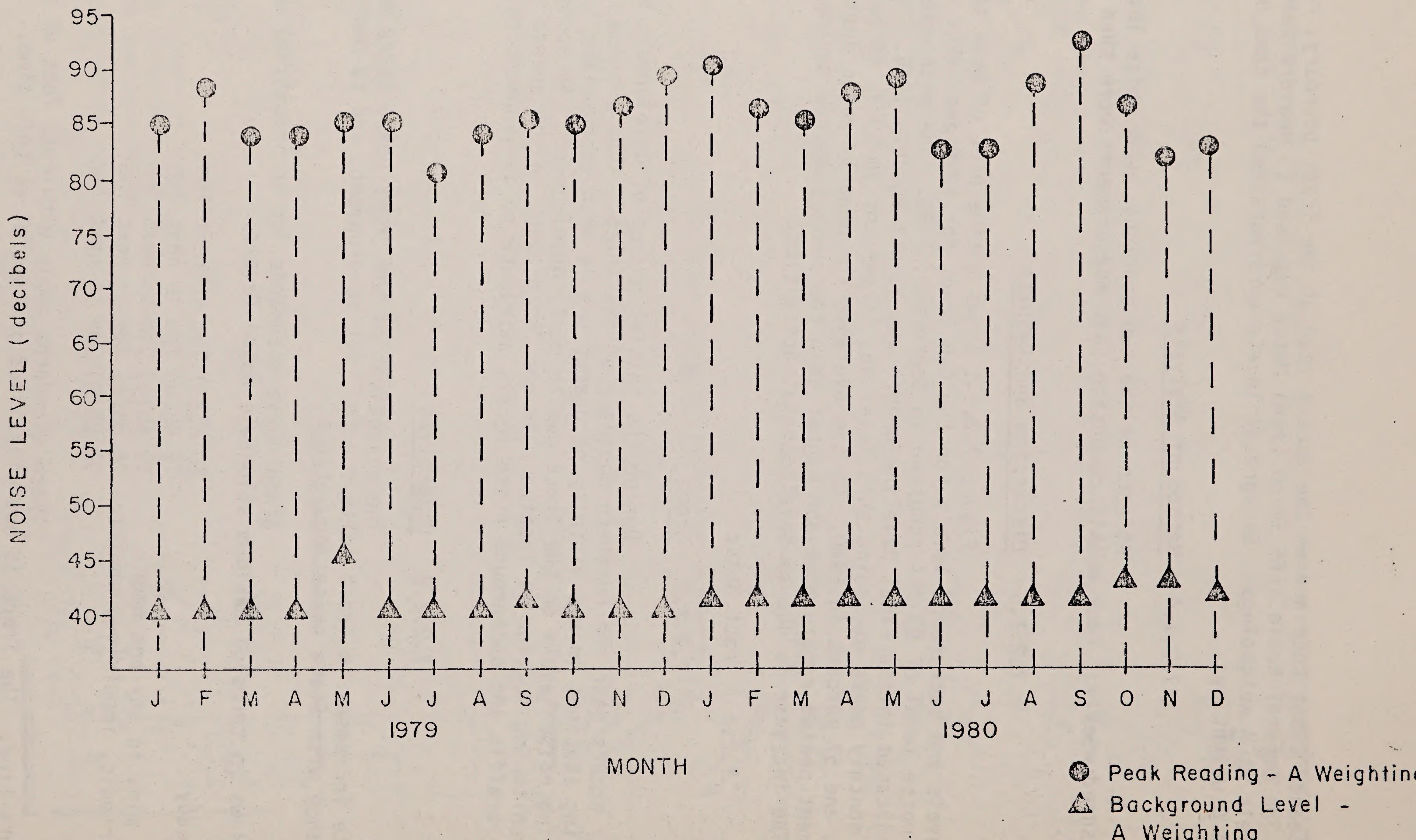


FIGURE 7.2.1-1
TRACT C-b PEAK TRAFFIC NOISE READINGS
(1979 - 1980)

7.2.2.3 Experimental Design

Continuous noise measurements are made at Stations NB01 and NB15 (Figure 7.1.1-1) on the northern boundary of the Tract for 24 hours every sixth day. The sensor recording system consists of Columbia Research Lab Inc. instruments: Model SPL110B, Serial Numbers 190 and 195. In this model the sound level meter is coupled to the battery operated recorder for 24 hours of unattended all-weather operations at an A-weighting.

7.2.2.4 Method of Analysis

Twelve-hour peaks (7am - 7pm and 7pm - 7am) are reported along with averages and background levels for each day of observations. Figure 7.2.2-1 presents the peak 12-hour Tract noise levels for both stations.

7.2.2.5 Discussion and Results

The peak Tract noise level reading of 83 dbA occurred on the first day of monitoring in February 1978; that peak did not exceed 90 dbA for 15 minutes in any hour. All other readings through December 1981 were 80 dbA or below from 0700 to 1900 and from 1900 to 0700.

7.2.3 Conclusions

Monthly peak traffic noise levels and background levels during the development period exceed those of the baseline period by an average of nine dbA. This increase is most likely due to development activity.

Noise levels in the Tract area due to development activities have, for the most part, remained low. Average levels of neither 12-hour period appear to have increased significantly over the development period.

Compliance with State noise standards for an industrial zone was achieved; the Tract is not classified industrial at this time.

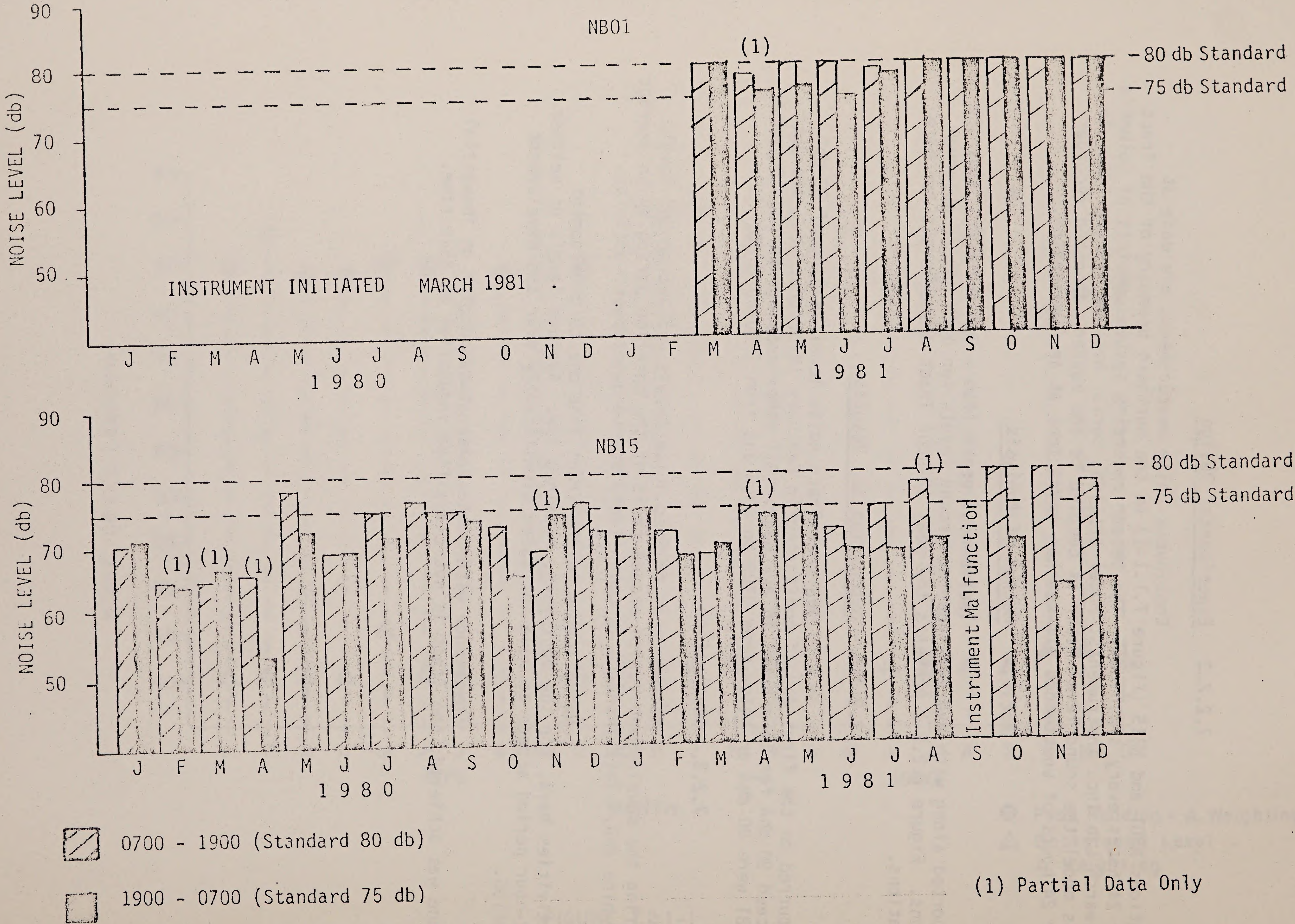


FIGURE 7.2.2-1

TRACT C-b HOURLY PEAK READINGS (db) FOR '80 - '81

8.0 BIOLOGY

8.1 Introduction and Scope

The goal of the biological monitoring program is to continue evaluation of biotic conditions and identify interactions with abiotic conditions in the Tract C-b ecological systems. The majority of monitoring parameters are those that provide information relative to early warning signals of change. The use of control and development sites permits the monitoring of long-term trends at affected and unaffected sites and the analysis of any corresponding differences developing over time at these sites. Monitoring sites are shown in Exhibit C.

8.2 Big Game: Mule Deer

Big game refers primarily to mule deer, since they are the only large mammals common to the C-b area apart from domestic cattle. Intensive studies of mule deer are justified since deer are a major herbivore of ecological importance and a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure.

Monitoring of mule deer attempts to show the significance of Tract C-b to their survival. This is accomplished through analysis of the following variables: 1) deer pellet group densities, 2) browse production and utilization, 3) migrational patterns and phenology, 4) road kills, 5) natural mortality, and 6) age-class composition. Study transect locations and sample sizes are based on baseline experience.

8.2.1 Deer Pellet Group Densities

8.2.1.1 Scope

Pellet group counts were conducted along 39 transects. Twelve transects were established this past year: nine in valley sagebrush habitat, which is undergoing a habitat enhancement program (brush beating); and three in chained rangeland habitat in close proximity to the water sprinkler system set out two years ago.

8.2.1.2 Objectives

The objectives of pellet group studies are to evaluate differences on a site specific basis and over time in order to make inferences regarding the possibility of positive or negative effects on deer due to development activities.

8.2.1.3 Experimental Design

Transects were located using a stratified random design, except at certain development locations where the placement of a transect was predetermined. Two strata (habitat types) were sampled: pinyon-juniper woodland and chained rangeland. All pellet group transects have a BA computer-code notation. Their exact locations are shown on the jacket map. Plots were raked in the fall and the pellet groups were counted in the spring.

8.2.1.4 Method of Analysis

All statistical analyses for the 1980-81 period are standard parametric procedures including the analysis of variance, t-test, product-moment correlation coefficient, and others.

8.2.1.5 Discussion and Results

Data on mule deer pellet group counts obtained from the 39 transects used during 1980-81 are shown in Tables 8.2.1-1 and 8.2.1-2. The results from 27 of these transects are also shown in Figures 8.2.1-1 and 8.2.1-2, along with pellet group count results obtained over the past three years. A discussion of within-year correlations on these data, and interrelationshops of pellet group counts, road counts, and browse studies is presented in Section 8.2.7. See Section 8.11.1 for discussion of brush beating transects.

Impact evaluations based on unusually low deer pellet group densities at selected transect locations were not made this year.

Transects BA20 and BA32, which are within the area of the sprinkler system, showed no suspiciously low values (see Figure 8.2.1-1), consequently no statistical tests for impacts were warranted. No other transect locations were in close proximity to new disturbances that occurred during the 1980-81 winter period.

8.2.1.6 Conclusions

Pellet group densities were lower in 1980-81 than in 1979-1980. Based on data collected, developmental activities of C-b Tract have not significantly affected deer pellet group densities within the study area.

8.2.2 Browse Production and Utilization

8.2.2.1 Scope

Studies of bitterbrush production and utilization were conducted along 19 transects, representing a total of 205 shrubs sampled. Transects were located in two habitat types: chained rangeland (13 transects); and pinyon-juniper (6 transects).

Studies of sagebrush utilization and age classes were conducted along 25 transects, representing a total of 1075 shrubs sampled. Transects were located in two habitat types: chained rangeland (13 transects); and pinyon-juniper (12 transects).

8.2.2.2 Objectives

The main objective of browse production and utilization studies is to quantify natural variation in range condition over time in order to permit evaluation of site specific changes which might be due to impacts or to mitigation.

Table 8.2.1-1. Deer pellet group densities, 1980-81.

Transect	Mean pellet groups per acre ± SE (n)*
Chained rangeland:	
BA17	150 ± 37.3 (20)
BA18	460 ± 68.6 (20)
BA25	240 ± 41.9 (20)
BA20	550 ± 76.3 (20)
BA21	615 ± 81.2 (20)
BA23	280 ± 57.9 (20)
BA01	415 ± 48.8 (20)
BA02	385 ± 67.4 (20)
BA03	295 ± 58.3 (20)
BA04	405 ± 65.5 (20)
BA05	365 ± 53.0 (20)
BA06	170 ± 34.1 (20)
BA07	130 ± 38.5 (20)
BA08	435 ± 60.4 (20)
BA09	185 ± 31.9 (20)
BA30	255 ± 50.5 (20)
BA31	280 ± 49.0 (20)
BA32	525 ± 93.4 (20)
Pinyon-juniper woodland:	
BA19	170 ± 26.3 (20)
BA26	85 ± 28.4 (20)
BA27	290 ± 66.1 (20)
BA16	120 ± 31.3 (20)
BA22	260 ± 52.0 (20)
BA24	155 ± 40.7 (20)
BA10	180 ± 28.7 (20)
BA11	130 ± 30.9 (20)
BA12	170 ± 37.1 (20)
BA13	215 ± 35.0 (20)
BA14	221 ± 33.8 (19)
BA15	105 ± 24.6 (20)
Brush-beaten sage:	
BA41	20 ± 11.7 (20)
BA42	15 ± 8.2 (20)
BA43	5 ± 5.0 (20)
BA44	275 ± 36.2 (20)
BA45	30 ± 16.4 (20)
BA46	5 ± 5.0 (20)
BA47	205 ± 42.0 (20)
BA48	230 ± 42.4 (20)
BA49	110 ± 21.6 (20)

* n = number of 0.01 acre plots sampled.

Table 8.2.1-2. Comparisons of pellet group counts in brush-beaten valley sagebrush with control areas.

RESULTS OF HIERARCHIAL ANOVA

Source of Variation	DF	MS	F	Variance Components
Between brush-beaten and control areas	1	3.68	7.7**	39.5%
Among transects	7	0.48	14.5***	24.4%
Among quadrats	171	0.03		36.1%

Transect means ± SE (n):

Brush-beaten		Control	
BA41	20 ± 11.7 (20)	BA43	5 ± 5.0 (20)
BA42	15 ± 8.2 (20)	BA44	275 ± 36.2 (20)
BA45	30 ± 16.4 (20)	BA47	205 ± 42.0 (20)
BA46	5 ± 5.0 (20)	BA48	230 ± 42.4 (20)
		BA49	110 ± 21.6 (20)

Conclusion:

Pellet group densities in control areas were significantly higher than in brush-beaten areas. See text for discussion.

** significance at $\alpha = 0.05$

*** significance at $\alpha = 0.01$

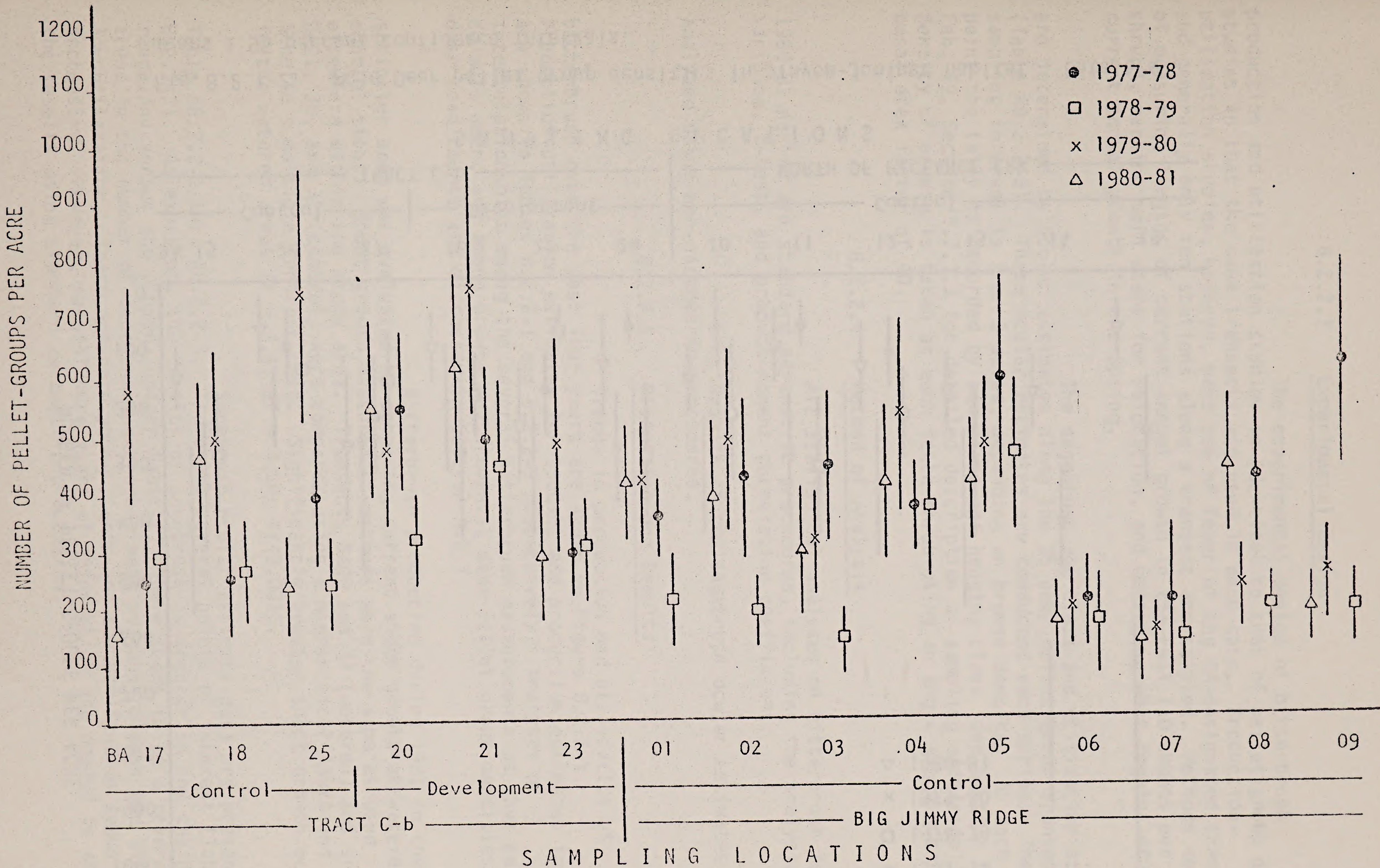


Fig. 8.2.1-1. Mule deer pellet group densities in chained rangeland habitat. Data are means ± 95 percent confidence intervals.

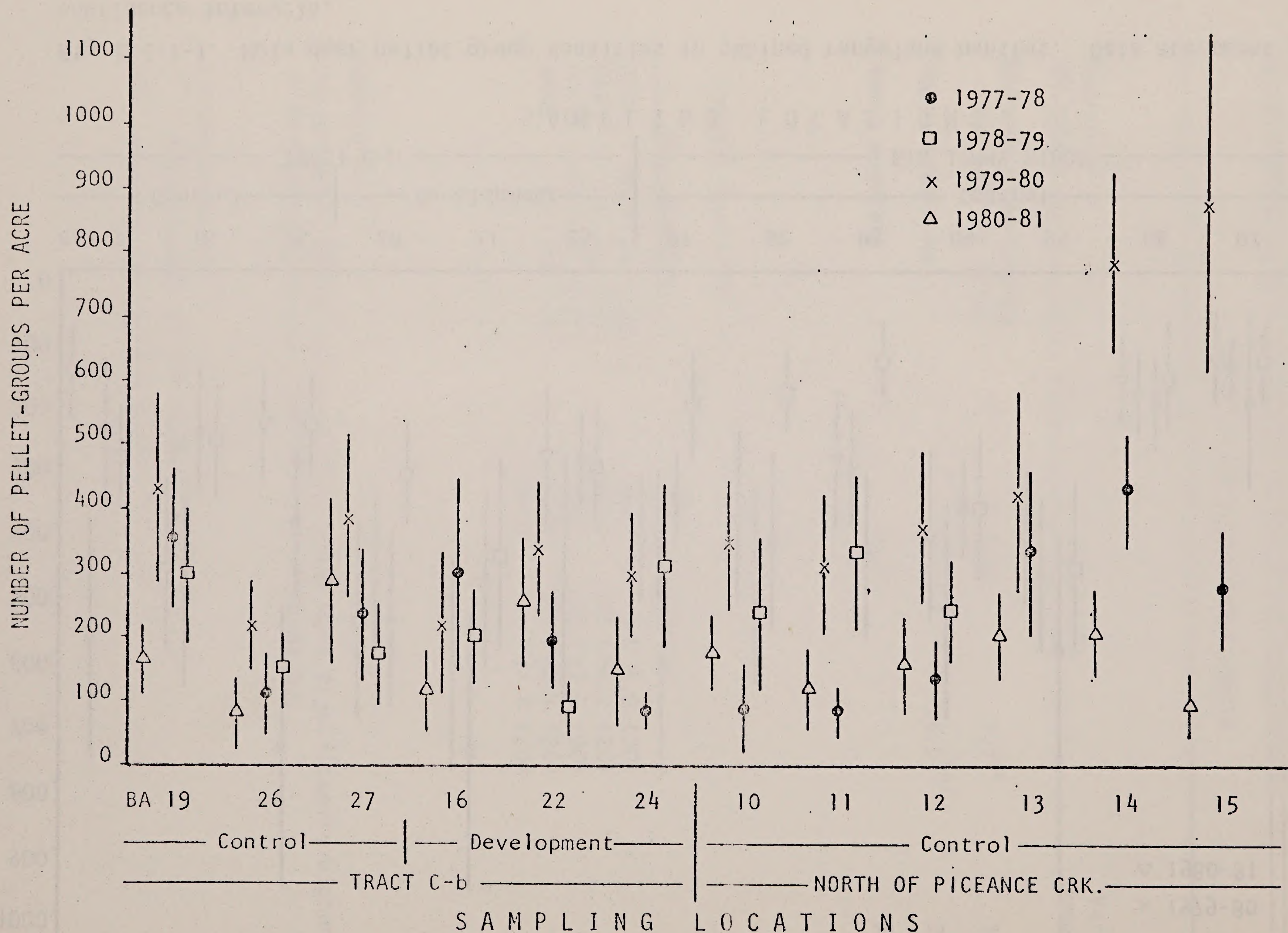


Fig. 8.2.1-2. Mule Deer pellet group densities in pinyon-juniper habitat. Data are means ± 95 percent confidence intervals.

8.2.2.3 Experimental Design

The experimental design of bitterbrush production and utilization studies is identical to that of pellet group density studies in that the same transects are used in each case. Production-utilization studies, however, make use of fewer of the BA-designated transects, and generally only ten stations along a transect are sampled. Methods consist of measuring lengths of current annual growth in the Fall (10 shoots per shrub), marking main stems for relocation, and measuring what remains of the current annual growth in the Spring.

The sagebrush age class and utilization studies are determined by ocular estimates along the 25 deer pellet group transects (Table A8.2.2-3). These ocular estimates are conducted each spring. The sampling interval is 2 or 3 paces, depending on browse density. At each sample point the tally is recorded by age class and hedging class (see Section DMP, Feb. 79, Section 8.7.3.3 for detailed description of sampling criterion). Density of browse is taken at each tenth shrub using an angle gauge with a basal area factor of 40.

8.2.2.4 Method of Analysis

All statistical analyses on bitterbrush for the 1980-81 period are standard parametric procedures, including the analysis of variance, t-test, and product-moment correlation coefficient.

Results of the sagebrush ocular estimates are analyzed using non-parametric procedures.

8.2.2.5 Discussion and Results

Trends in production and utilization of bitterbrush over the past four years are shown in Figure 8.2.2-1. Production-utilization estimates for 1980-81 and production estimates for 1980 are shown in Tables 8.2.2-1 and 8.2.2-2 respectively. Analyses of interrelationships among the several bitterbrush measurements as they pertain to mule deer, and among browse measurements, deer pellet group densities, and deer road counts are discussed in Section 8.2.7.

Bitterbrush production during 1981 in the water sprinkler area was evaluated by comparing current shoot growth at watered and control sites. Shoot growth measurement methods were the same as used elsewhere within the study area. Transects BA20 and 32 (watered) and transects BA21, 30, and 31 (control) were compared using a hierarchical ANOVA and a Scheffe's multiple contrast test. Significantly greater short growth occurred in the watered areas ($F = 7.4$; $df = 4,60$; $P \ll 0.001$).

Sagebrush ocular estimate data are presented in Table A8.2.2-1 thru A8.2.2-3. There are several points of interest (Table 8.2.2-3). As expected, the density of sagebrush is greater in the chained rangeland versus the pinyon-juniper habitat. There seems to be a reversing trend in the number of decadent sagebrush plants vs young plants and high vs low utilization. There are more young plants and the utilization seems to be decreasing. However, several more years of information are needed to analyze the results using standard parametric procedures.

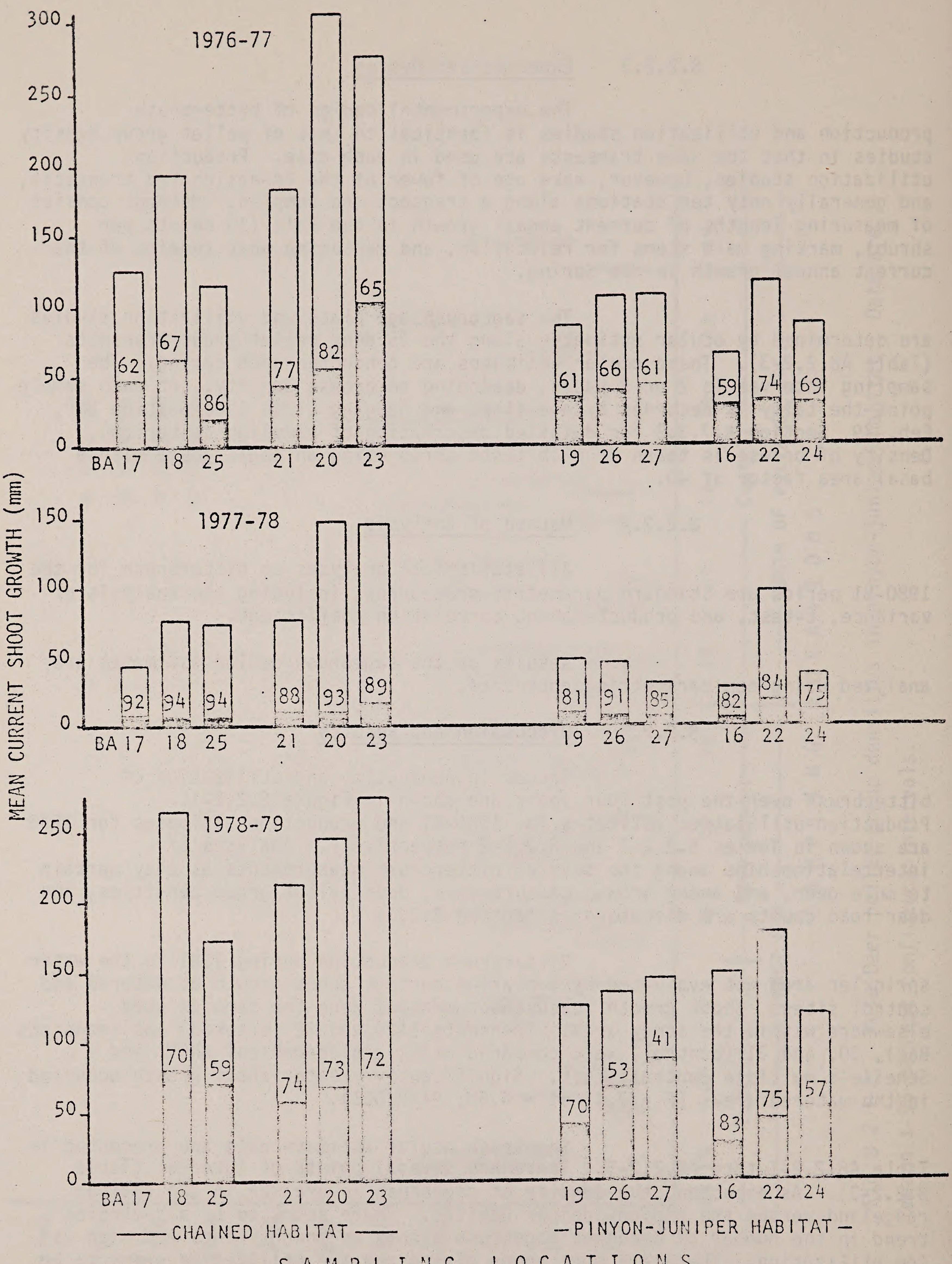


Fig. 8.2.2-1. Trends in production and utilization of bitterbrush. Bars represent mean current shoot growth. Shaded areas represent the current growth remaining after winter browsing. Numbers inside bars represent the percent of current shoot growth consumed by deer. Transect numbers are below bars.

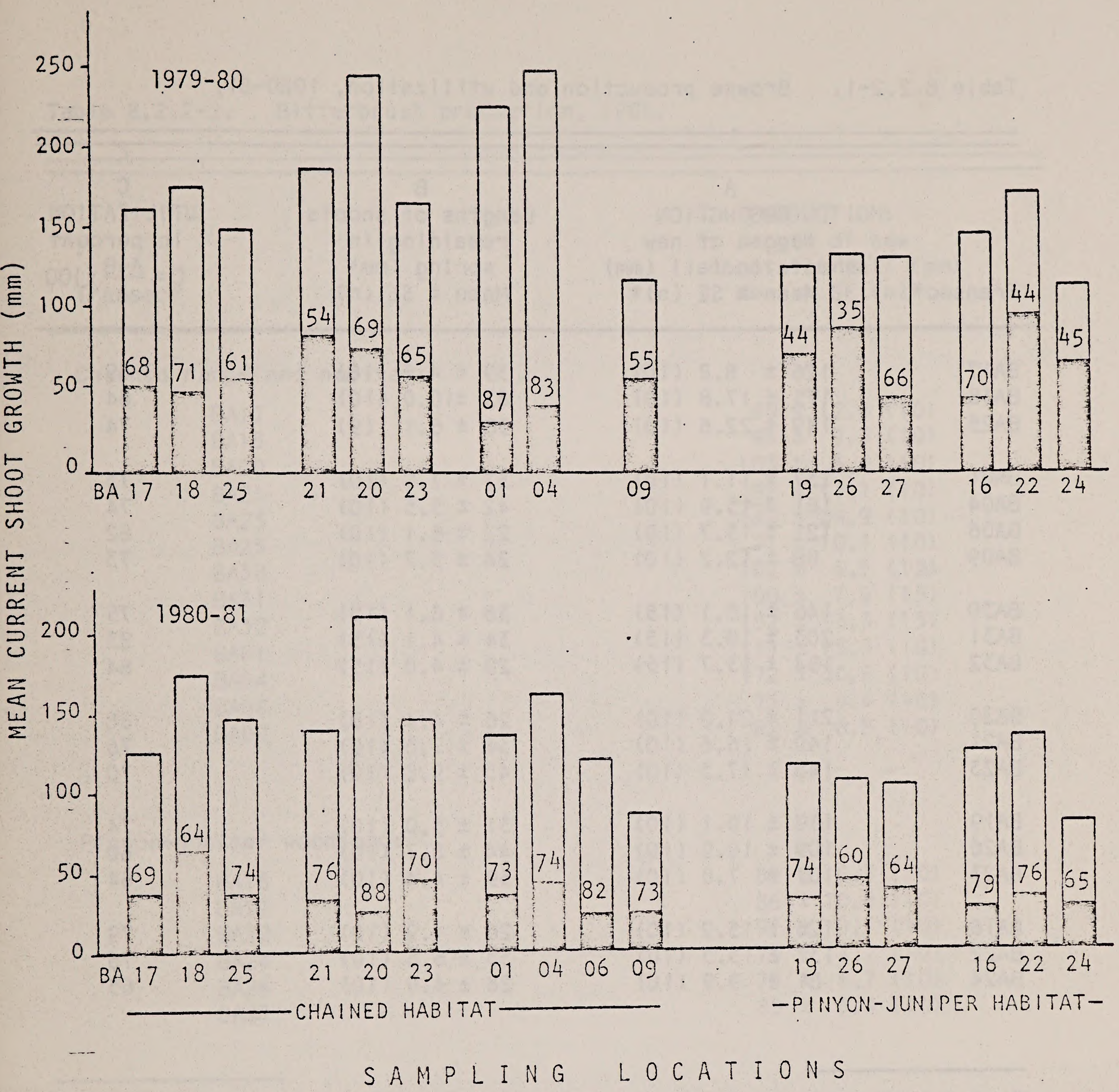


Fig. 8.2.2-1 (cont). Trends in production and utilization of bitterbrush. Bars represent mean current shoot growth. Shaded areas represent the length of current shoot growth remaining after winter browsing. Numbers inside the bars represent the percent of current shoot growth consumed by deer. Transect numbers are indicated below bars.

Table 8.2.2-1. Browse production and utilization, 1980-81.

Transect	A PRODUCTION length of new shoots in fall (mm) Mean ± SE (n)*	B Lengths of shoots remaining in spring (mm) Mean ± SE (n)	C UTILIZATION in percent $C = \frac{A-B}{A} \times 100$
BA17	126 ± 8.8 (10)	39 ± 4.3 (10)	69
BA18	175 ± 17.8 (10)	63 ±10.0 (10)	64
BA25	149 ± 22.6 (10)	38 ± 6.1 (9)	74
BA01	137 ± 11.1 (10)	37 ± 7.0 (10)	73
BA04	161 ± 15.9 (10)	42 ± 5.5 (10)	74
BA06	121 ± 13.7 (10)	22 ± 6.1 (10)	82
BA09	88 ± 12.2 (10)	24 ± 5.7 (10)	73
BA30	146 ± 15.1 (15)	36 ± 8.1 (15)	75
BA31	203 ± 10.3 (15)	34 ± 4.1 (15)	83
BA32	184 ± 13.7 (15)	29 ± 4.0 (15)	84
BA20	211 ± 24.0 (10)	26 ± 4.4 (10)	88
BA21	140 ± 16.6 (10)	34 ± 7.6 (10)	76
BA23	148 ± 17.3 (10)	45 ± 9.8 (10)	70
BA19	119 ± 10.1 (10)	31 ± 5.0 (10)	74
BA26	109 ± 10.9 (10)	44 ± 8.7 (10)	60
BA27	107 ± 7.0 (10)	39 ± 4.4 (10)	64
BA16	126 ± 15.9 (10)	26 ± 4.9 (10)	79
BA22	137 ± 15.5 (10)	33 ± 6.6 (10)	76
BA24	81 ± 9.9 (10)	28 ± 4.0 (10)	65

* n = number of shrubs sampled.

Table 8.2.2-2. Bitterbrush production, 1981.

Transect	PRODUCTION: length of new shoots in fall (mm) Mean ± SE (n)*
Chained rangeland habitat:	
BA17	99 ± 12.6 (10)
BA18	93 ± 9.3 (10)
BA20	103 ± 6.4 (10)
BA21	82 ± 11.1 (10)
BA23	144 ± 24.9 (10)
BA25	71 ± 10.1 (10)
BA30	102 ± 6.5 (15)
BA31	100 ± 7.9 (15)
BA32	152 ± 13.3 (15)
BA01	111 ± 15.3 (10)
BA04	172 ± 30.8 (10)
BA06	75 ± 9.4 (10)
BA09	82 ± 8.5 (10)
Pinyon-juniper woodland:	
BA16	87 ± 6.3 (10)
BA19	86 ± 10.8 (10)
BA22	97 ± 9.7 (10)
BA24	71 ± 7.7 (10)
BA26	75 ± 6.7 (10)
BA27	85 ± 5.4 (10)

* n = number of shrubs sampled.

TABLE 8.2.2-3

SAGEBRUSH OCULAR ESTIMATE
1978 - 1981

CHAINED P-J HABITAT

Year	Sample Size	Young	Mature	Decadent	Low	Medium	High	Shrub[1] Density
1978	500	26	456	18	186	215	99	169
1980	650	127	477	44	353	261	36	208
1981	650	187	446	17	422	208	20	159

PINYON JUNIPER HABITAT

Year	Sample Size	Young	Mature	Decadent	Low	Medium	High	Shrub[1] Density
1978	465	0	226	239	27	188	250	74
1980	475	11	249	215	84	184	207	78
1981	425	6	324	95	195	170	60	79

1 $\text{Sagebrush plants/acre} = \frac{\text{Number of shrubs counted}}{\text{Number of sample points}} \times \text{Basal Area Factor}$

BAF = 40

8.2.2.6 Conclusions

Bitterbrush utilization in 1980-81 was higher than in 1979-80; 72% vs 61%. Sagebrush density is remaining fairly constant. Browse utilization has not been significantly affected by developmental activities of Tract C-b.

8.2.3 Migrational Patterns and Phenology

8.2.3.1 Scope

Deer road counts have proven useful for showing deer distributions along the Piceance Creek highway. The structural road count observations are repeatable, and provide a means of quantifying changes in relative abundance and distribution.

8.2.3.2 Objectives

The main objectives of deer road count studies are to document the distributional patterns of deer along the Piceance Creek drainage during the Fall-through-Spring period, and to record the times of the seasonal migrational movements.

8.2.3.3 Experimental Design

Counts were made at approximately weekly intervals beginning in mid-September and ending in May. Observations were made along 41 miles of highway, from Highway 64 on the White River to Highway 13 at Rio Blanco. Counts were made from a vehicle driving approximately 30 m.p.h. The direction of vehicle travel was changed for each consecutive weekly count. Deer were recorded for one-mile intervals, according to feeding locations on slopes or in meadows. Stations are shown on Exhibit C (found in the back cover jacket of this volume).

8.2.3.4 Method of Analysis

At the present time, data are evaluated by comparisons of histograms showing numbers of deer observed along the Piceance Creek road at selected periods throughout the winter.

8.2.3.5 Discussion and Results

Mule deer arrived in the Tract C-b area from summer range during the mid-October period, and left in spring during late April. This timing has been quite consistent over the past seven years, as evidenced by road count studies. During this past year, however, far fewer deer were recorded during road counts than have been observed previously (Figure 8.2.3-1). It is assumed that this was due to the very mild and snow free winter of 1980-81. Apparently deer utilized agricultural meadows along the Piceance Creek road less than in past years. For a discussion of the interrelationships of deer road counts, bitterbrush studies, and deer pellet group counts, see Section 8.2.7.

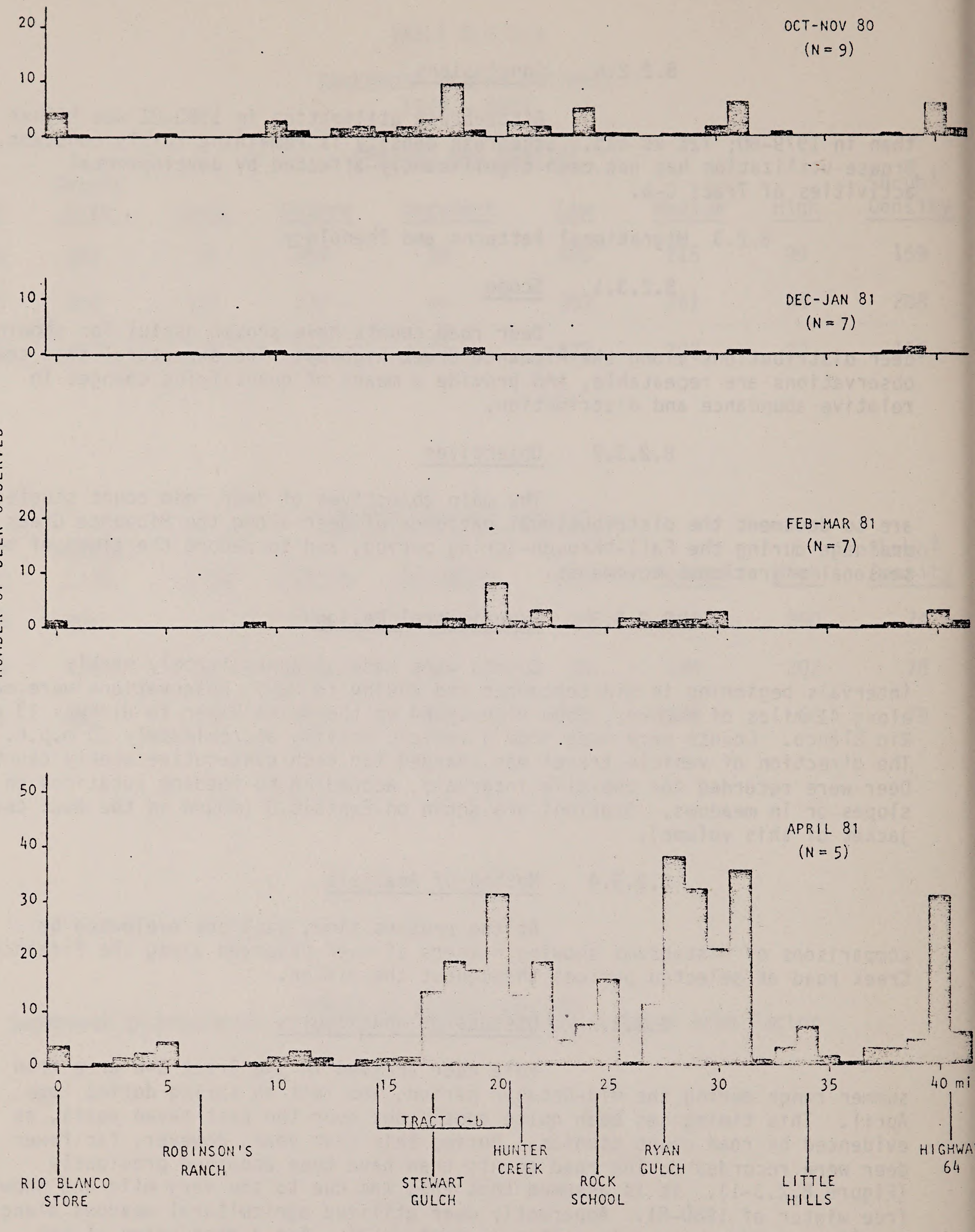


Fig. 8.2.3-1. Summary of deer road counts for 1980-81. Heights of bars are means; sample sizes (N) are the number of road counts for the period.

8.2.3.6 Conclusions

The highest road count in the 1980-81 study was 494 deer in April. There were no indications of a displacement of deer from the meadows in the Tract C-b vicinity. The migrational movements and distribution of mule deer along the highway have not been significantly affected by the construction activities on Tract C-b.

8.2.4 Road Kill

8.2.4.1 Scope

Mule deer road-kill data were collected weekly along Piceance Creek highway to obtain information on the number and location of deer killed by vehicles on the highway.

8.2.4.2 Objectives

The main objectives of collecting road kill data were to obtain accurate mule deer fatality estimates and to use this information in conjunction with other deer study data to identify problem areas so the necessary mitigative measures could be initiated.

8.2.4.3 Experimental Design

Weekly road kill data were collected from September 1980 through May 1981 at the same stations used for mule deer migrational patterns and phenology study. The dead deer were aged, sexed, and tagged. In addition, one ear was removed to avoid double counting. Road kill information was compared to Division of Wildlife information collected to ensure that all deer found were recorded.

8.2.4.4 Method of Analysis

Currently, time series tabulations and graphs are used for analysis. When several additional years of data have been collected, nonparametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) may be used.

8.2.4.5 Discussion and Results

Mule deer roadkill data for 1977 thru 1981 are show in Table 8.2.4-1. A comparison of 79-80 to 80-81 data shows a 70% reduction in kills in 1980-1981. This drop in roadkills is probably attributable to the mild winter and the reduced deer population. The data also show a decreasing trend of roadkills over the years. This is not surprising, since the deer herd has been declining over the past several years; due mostly to two large winter kills.

Data on age and sex classes of roadkills is also presented is Table 8.2.4-1. A trend seems to becoming apparent. Each year, the most frequent class of deer hit is mature does, followed by female fawns, male fawns and mature bucks. The only exception was in 78-79 where more male fawns were killed than female fawns. A possible explanation of this trend

TABLE 8.2.4-1

Piceance Creek Road Kill

(Piceance Creek Road from 0 thru Mile 41)

Date	DOES		FAWNS				BUCKS		Unknown	Total
			Male		Female					
	#	%	#	%	#	%	#	%		
9/80-5/81	12	43	3	11	6	22	2	7	5	28
9/79-5/80	40	41	22	22	26	27	3	3	5	96
9/78-5/79	80	61	13	10	27	21	11	8	0	131
9/77-5/78	40	41	28	29	22	22	8	8	2	100*

*Total road kill was 125 deer. This figure was derived from combining DOW data with C-b data.

could be related to deer population size and habits. More mature does are probably killed than other deer because they represent the largest segment of the population. More female fawns may be getting killed because they stay closer to the does than male fawns. Thus when a doe crosses the road, the female fawns may try crossing even though a vehicle is coming, whereas, a male fawn may not rush blindly after the doe.

Total deer roadkills for the Piceance Creek Highway are presented in Figure 8.2.4-1. Over 62% of the deer killed have been hit between miles 0 to 20. This section of the highway receives the most traffic.

8.2.4.6 Conclusions

Roadkill data seem to be starting to indicate that deer herd size and weather conditions influence the number of deer/vehicle collisions more so than the amount of vehicular traffic.

8.2.5 Natural Mortality

8.2.5.1 Scope

Baseline studies have shown winter kills to be largely restricted to the lateral draws and bottomland sagebrush. Checking these areas each spring has helped in observing changes in the relative magnitude of deer mortality.

8.2.5.2 Objectives

The objectives of this study are to estimate deer mortality on a yearly basis in order to document long-term trends and to aid interpretations of other deer data.

8.2.5.3 Experimental Design

Sampling was done in the spring on 10 plots located in lateral draws and sagebrush gulches (see Exhibit C). The age and sex of all deer that had died the previous winter were recorded, and each carcass marked with a metal tag stamped with the current year. The presence of either the skull of pelvic girdle was required to constitute a carcass.

8.2.5.4 Method of Analysis

Nonparametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) will be used when several additional years of data have been gathered. Only tabular presentations will be used until then.

8.2.5.5 Discussion and Results

The number of deer carcasses identified from the winter of 1980-81 was lower than had been recorded since 1975-76 (Table 8.2.5-1). Only 16 carcasses were found in 174 acres of sagebrush and lateral draw habitat. The low winter kill suggested by these findings probably relates to the mild winter conditions.

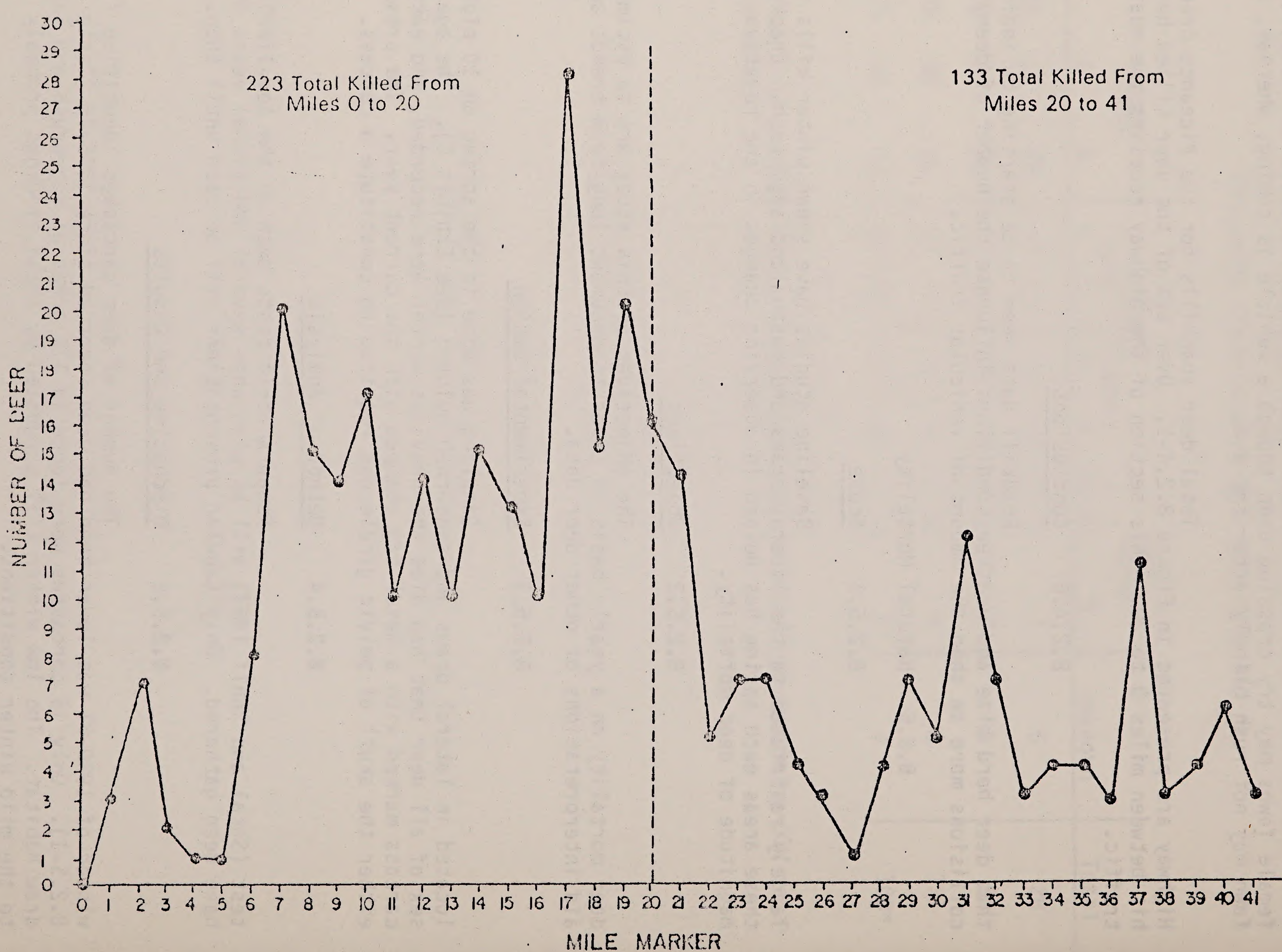


FIGURE 8.2.4-1
CUMLATIVE PICEANCE CREEK ROAD KILL

Table 8.2.5-1. Results of deer mortality studies.

Year	Sampling Location	No. of carcasses found	Hectares sampled (acres)	Carcasses per hectare (/acre)
1974-75	Lateral draws	11	7.25 (18)	1.52 (0.61)
1975-76	Lateral draws	8	7.25 (18)	1.10 (0.44)
1976-77	Interim monitoring period - No sampling			
1977-78	Sagebrush lateral draw	25	70.5 (174)	0.355 (0.144)
1978-79	Sagebrush-lateral draw	34	70.5 (174)	0.482 (0.195)
1979-80	Sagebrush-lateral draw	60	70.5 (174)	0.851 (0.345)
1980-81	Sagebrush-lateral draw	16	70.5 (174)	0.227 (0.092)

8.2.5.6 Conclusions

Only 16 carcasses were found in 1981 as compared to 60 in 1980. Activities on C-b Tract do not seem to be effecting the natural mortality in the study area.

8.2.6 Age-Class Composition

8.2.6.1 Scope

Estimating the age-class composition of the deer herd in the fall facilitates evaluating the magnitude of fawn mortality that occurred during spring and summer while deer were on summer range. Estimates taken in spring permit estimating the fawn mortality that occurred while deer were on winter range in the C-b area.

8.2.6.2 Objectives

The main objective of the age-class study is to estimate fawn-adult ratios in fall and in spring.

8.2.6.3 Experimental Design

Sampling locations were restricted to the meadows of major drainages within five miles of Tract C-b. Counts occurred in November and in April. Observations took place during times of high concentrations. The deer that could be clearly observed were recorded as adults, bucks, does or fawns. No attempt was made to recognize yearlings.

8.2.6.4 Method of Analysis

Data from this study will be used mainly to aid in the interpretation of the results of other deer studies.

8.2.6.5 Discussion and Results

Fall counts of deer were not feasible this past year, since very few deer were observable from the road. Presumably this was due to the mild weather. In spring, an age-class estimate was made, but, the sample size was small. Only 92 deer were observed; 24 were fawns, resulting in a fawn-doe ratio of 35.2:100 (Table 8.2.6-1). Generalizations regarding trends or winter mortality based on these data would be questionable in view of the small sample size.

8.2.6.6 Conclusions

Mule deer did not concentrate in large enough numbers to obtain adequate data to determine age class ratios.

8.2.7 Interrelationships of Mule Deer Studies

Discussions in previous annual reports regarding deer monitoring have emphasized quantifying the variation within the ecosystem and developing techniques for detecting changes due to impacts or to mitigation

Table 8.2.6-1. Age class composition of mule deer wintering near tract C-b.

Date	Fawns	Does	Bucks	Adults	Fawns/ 100 Does	Bucks/ 100 Does	Fawns/ 100 Adults
1977 Nov 15-23	85	107	28	135	79.4	26.2	63.0
1978 Apr 4-7	68			104			65.0
1978 Nov 13-27	151	159	35	194	95.0	22.0	77.8
1979 Apr 20-26	41			343			12.0
1979 Nov 27-Dec 7	46	62	8	70	74.1	12.9	65.7
1980 Apr 21-24	26			375			6.9
1980 November	No count						
1981 Apr 25	24			68			35.2

attempts. Emphasis this year, however, has been placed on the degree of correlation among the three main indicator variables that are being used to monitor changes in localized deer number (pellet group counts, bitterbrush condition, and road counts). Because only five years of monitoring data are presently available, descriptions of trends and correlations over time are still tentative. Nevertheless, analyses are initiated at this time because of the importance of estimating the extent to which the separate deer studies agree. Very close agreement would of course be fortunate in that relatively small changes in deer numbers, or in localized distributions, could be detected. Presently, however, as the following discussion will show, there is only a fair amount of agreement. But it should be kept in mind that five years are a small sample size when year-to-year variation is being evaluated, and that statistical correlations of two variables over five years suffer from having only three degrees of freedom.

Trends in bitterbrush production, utilization, and hedging (Figure 8.2.7-1) suggest that the higher the production (as measured by shoot elongation in the fall), the less the utilization by deer during the following winter. The negative correlation is statistically significant: r = -0.89; df = 3 (Table 8.2.7-1). This finding is to be expected, however, since utilization is expressed as the percent of current shoot growth consumed, not the actual amount consumed (if the same weight of forage were consumed during two winters, the year with the higher productivity would show a lower percent utilization). That hedging (length of shoots remaining in spring) is correlated with percent utilization is merely a consequence of the relationship: utilization = (production - hedging) ÷ production.

In terms of the interrelationships among the component deer studies, the degree of correspondence between pellet group counts, and bitterbrush measurements is of considerable interest. As can be seen (Figures 8.2.7-1, 8.2.7-2 (a) and (b), and Table 8.2.7-2) correlations are weak between any selected pairs. Deer road counts and pellet group counts, however, have varied together over all years except 1978-79 (Figure 8.2.7-2). Perhaps the severe winter of that year was responsible for the one conspicuous anomaly. When 1978-79 data are omitted from correlation analyses (Table 8.2.7-2) a high correlation (r = 0.89) is obtained between road counts and pellet counts for the chained rangeland habitat. Omitting this one year's data did little to improve other correlation

It can only be concluded at this time that correlations are weak at best between road counts, pellet counts, and browse measurements, and that more definitive conclusions will have to be postponed for probably several more years.

Between-year correlations of pellet group counts (Table 8.2.7-3) demonstrate that rarely do any pair of years correspond. This implies that during each winter the deer forage over the study area in some nonsystematic, perhaps random, way. Apparently, certain ridgetops, hillsides, or other microhabitat situations are not being preferred year after year. The same conclusion is arrived at when bitterbrush data are evaulated for between-year correlations (Table 8.2.7-4). One might assume, therefore, that deer seek out the most nutritious shrubs each winter, and that the distribution of such shrubs, or patches of shrubs, changes each year (influenced to a large

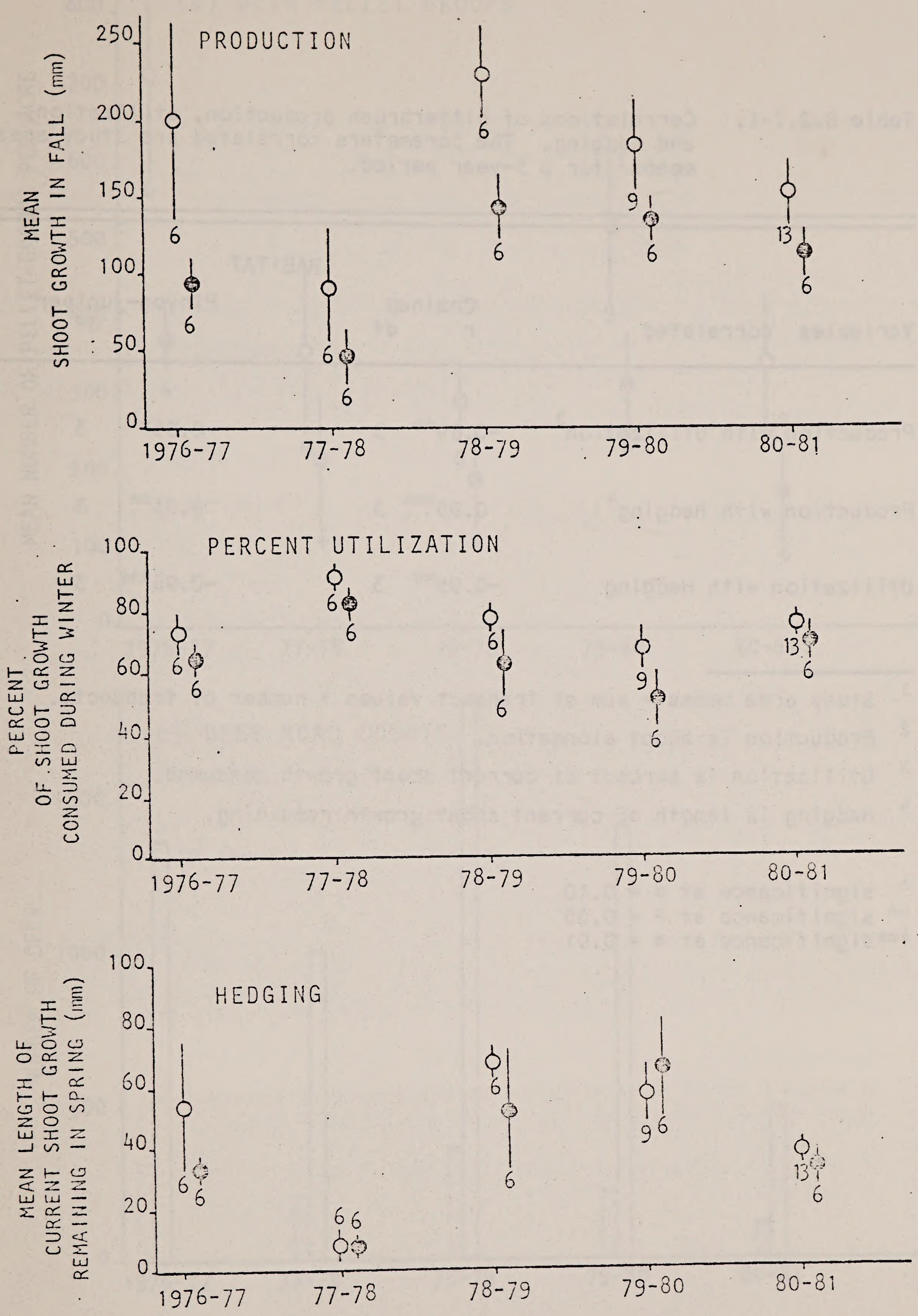


Fig. 8.2.7-1. Trends in bitterbrush production, utilization and hedging. Data shown are means ± 95% confidence intervals. Open circles are values for chained rangeland habitat; closed circles are for pinyon-juniper habitat. Sample sizes (a sample is a transect mean) are shown next to the circles. For correlation coefficients, see Table 8.2.7-1.

Table 8.2.7-1. Correlations of bitterbrush production, utilization, and hedging. The parameters correlated are study area means[1] for a 5-year period.

	HABITAT			
	Chained		Pinyon-juniper	
Variables correlated	r	df	r	df
Production[2] with Utilization[3]	-0.89**	3	-0.85*	3
Production with Hedging[4]	0.99***	3	0.93**	3
Utilization with Hedging	-0.95**	3	-0.96***	3

1 Study area means = sum of transect values ÷ number of transects.

2 Production is shoot elongation.

3 Utilization is percent of current shoot growth consumed.

4 Hedging is length of current shoot growth remaining.

* significance at $\alpha = 0.10$
** significance at $\alpha = 0.05$
*** significance at $\alpha = 0.01$

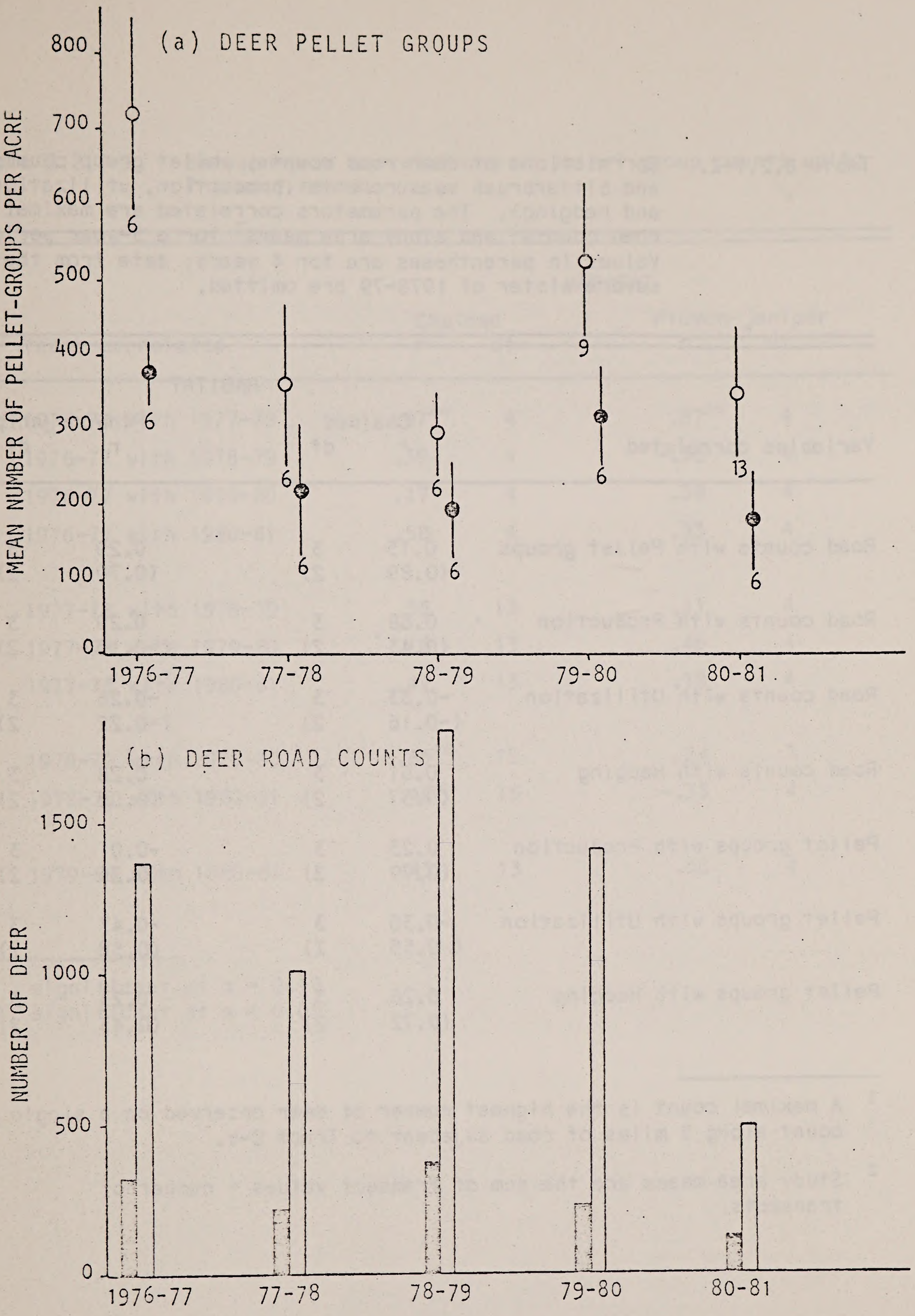


Fig. 8.2.7-2. Trends in deer pellet group counts and road counts. For (a), data are means ± 95% confidence intervals. Open circles are values for chained rangeland habitat; closed circles are for pinyon-juniper habitat. Sample sizes (transect means) are shown under circles. For (b), bars are maximum counts of deer. Open bars are the highest total count along 41 miles of road, from Rio Blanco to the White River; shaded bars are the highest total count along 5 mi. of road bordering Tract C-b. For correlation coefficients, see Table 8.2.7-2.

Table 8.2.7-2. Correlations of deer road counts, pellet group counts, and bitterbrush measurements (production, utilization, and hedging). The parameters correlated are maximal road counts[1] and study area means[2] for a 5-year period. Values in parentheses are for 4 years; data from the severe winter of 1978-79 are omitted.

	HABITAT			
	Chained		Pinyon-juniper	
Variables correlated	r	df	r	df
Road counts with Pellet groups	0.15 (0.89	3 2)	0.29 (0.70	3 2)
Road counts with Production	0.68 (0.43	3 2)	0.29 (-0.15	3 2)
Road counts with Utilization	-0.33 (-0.16	3 2)	-0.26 (-0.22	3 2)
Road counts with Hedging	0.61 (0.37	3 2)	0.28 (0.06	3 2)
Pellet groups with Production	0.23 (0.79	3 2)	-0.01 (0.26	3 2)
Pellet groups with Utilization	-0.30 (-0.55	3 2)	-0.47 (0.58	3 2)
Pellet groups with Hedging	0.26 (0.72	3 2)	0.23 (0.43	3 2)

[1] A maximal count is the highest number of deer observed on a single count along 5 miles of road adjacent to Tract C-b.

[2] Study area means are the sum of transect values ÷ number of transects.

Table 8.2.7-3. Between-year correlations of pellet group counts using transect means.

	HABITAT			
	Chained		Pinyon-juniper	
Years correlated	r	df	r	df
1976-77 with 1977-78	.97**	4	.87**	4
1976-77 with 1978-79	.39	4	-.36	4
1976-77 with 1979-80	.17	4	.30	4
1976-77 with 1980-81	.58	4	.33	4
1977-78 with 1978-79	.35	13	.11	4
1977-78 with 1979-80	.16	13	.46	4
1977-78 with 1980-81	.42	13	.18	4
1978-79 with 1979-80	.65**	13	.24	7
1978-79 with 1980-81	.46*	15	-.33	4
1979-80 with 1980-81	.43	13	.68	4

* significant at $\alpha = 0.10$
** significant at $\alpha = 0.05$

Table 8.2.7-4. Between-year correlations of bitterbrush measurements (production, utilization, and hedging) using transect means.

	HABITAT			
	Chained		Pinyon-juniper	
Years correlated	r	df	r	df
PRODUCTION:				
1976 with 1977	0.92**	4	0.58	4
1976 with 1978	0.72	4	0.47	4
1976 with 1979	0.74	4	0.36	4
1976 with 1980	0.70	4	0.12	4
1976 with 1981	0.66	4	0.21	4
1977 with 1978	0.54	4	0.60	4
1977 with 1979	0.57	4	0.71	4
1977 with 1980	0.64	4	0.57	4
1977 with 1981	0.65	4	0.63	4
1978 with 1979	0.29	4	0.92**	4
1978 with 1980	0.37	4	0.75*	4
1978 with 1981	0.79*	4	0.06	4
1979 with 1980	0.70**	10	0.91**	4
1979 with 1981	0.50*	10	0.87**	4
1980 with 1981	0.33	11	0.90**	4
UTILIZATION:				
1976-77 with 1977-78	0.25	4	-0.06	4
1976-77 with 1978-79	-0.63	4	0.03	4
1976-77 with 1979-80	-0.42	4	-0.62	4
1976-77 with 1980-81	0.69	4	-0.10	4
1977-78 with 1978-79	-0.49	4	-0.24	4
1977-78 with 1979-80	0.63	4	-0.17	4
1977-78 with 1980-81	-0.03	4	-0.31	4
1978-79 with 1979-80	0.18	4	0.10	4
1978-79 with 1980-81	0.04	4	0.91**	4
1979-80 with 1980-81	0.18	10	0.37	4
HEDGING:				
1976-77 with 1977-78	0.67	4	-0.48	4
1976-77 with 1978-79	0.41	4	0.85**	4
1976-77 with 1979-80	-0.17	4	-0.05	4
1976-77 with 1980-81	0.36	4	0.81**	4
1977-78 with 1978-79	0.22	4	-0.38	4
1977-78 with 1979-80	0.36	4	0.61	4
1977-78 with 1980-81	-0.24	4	-0.36	4
1978-79 with 1979-80	-0.46	4	-0.11	4
1978-79 with 1980-81	0.64	4	0.73*	4
1979-80 with 1980-81	-0.14	10	0.38	4

* significant at $\alpha = 0.10$
** significant at $\alpha = 0.05$

extent by past deer browsing, one would suspect). Although this hypothesis seems reasonable, it gains no support from within-year correlations of pellet counts and browse measurements based on either transect or quadrat data (Tables 8.2.7-5 and 8.2.7-6 respectively). Again, rarely is there a correlation. This does not necessarily mean, however, that the above hypothesis is unsound, but it does suggest that on this spatial scale deer defecation and browse utilization do not occur with equal intensity at the same spot.

As mentioned earlier, a close correspondence between the results of the separate deer studies would permit detecting rather subtle changes in the local deer herd. Yet, even with the weak correlations demonstrated here, important man-induced changes are nonetheless identifiable with the methods presently in use. The conclusion to be made regarding impacts to deer up to this point in time, therefore, is that wintering deer in the Tract C-b area apprear to be using the habitat much as they did during the pre-development period. No localized declines in numbers or evidence of major displacements have been found, which is testimony to the behavioral adaptability of the mule deer.

8.3 Medium-Sized Mammals

Studies of medium-sized mammals are restricted to coyotes and lagomorphs (cottontails and jackrabbits). Monitoring of these animal groups provides trend information on the relative abundance of larger mammalian predators to prey species present within the Tract C-b ecosystem.

8.3.1 Coyote Abundance

8.3.1.1 Scope

Coyotes are of ecological significance because they are a major predator on Tract C-b. They are also of general interest to the public with both strongly negative and positive supporters.

8.3.1.2 Objectives

The objective of the coyote study is to obtain trend information on the relative abundance of coyotes on and near Tract C-b.

8.3.1.3 Experimental Design

Two coyote scent-station surveys are being used following the design of the U.S. Fish and Wildlife Service (Linhart and Knowlton 1975). Sampling was done in early October along 30 miles of road segments on and near the Tract. The presence of tracks was checked once the day after scent stations were placed. This survey technique is also being used to record information on wildlife species other than coyotes.

8.3.1.4 Method of Analysis

Relative abundance is calculated as a visit frequency. The long-term trend data being gathered on Tract will be evaluated in the context of the state-wide data gathered by the U.S. Fish and Wildlife Service.

Table 8.2.7-5. Within-year correlations of pellet group counts (PG) with bitterbrush measurements (utilization, hedging, and production). Parameters used for correlations are transect means.

	HABITAT			
	Chained		Pinyon-juniper	
Variables correlated	r	df	r	df
1976-77				
PG with Utilization	.82**	4	-.38	4
PG with Hedging	-.33	4	.08	4
PG with Production	.41	4	-.14	4
1977-78				
PG with Utilization	-.17	4	-.07	4
PG with Hedging	.25	4	-.04	4
PG with Production	.36	4	-.10	4
1978-79				
PG with Utilization	.56	4	-.03	4
PG with Hedging	-.54	4	-.26	4
PG with Production	.06	4	-.87*	4
1979-80				
PG with Utilization	.01	7	-.01	4
PG with Hedging	.45	7	-.01	4
PG with Production	.07	7	-.11	4
1980-81				
PG with Utilization	.26	11	.10	4
PG with Hedging	.14	11	.07	4
PG with Production	.56**	11	.21	4

* significant at $\alpha = 0.10$
** significant at $\alpha = 0.05$

Table 8.2.7-6. Within-year correlations of pellet group counts with bitterbrush measurements (utilization and hedging). Parameters used for correlations are quadrat values.

Variables correlated	HABITAT Chained rangeland r	df
1980		
Pellet groups with Utilization	-.13	88
Pellet groups with Hedging	.20	88
1981		
Pellet groups with Utilization	.09	97
Pellet groups with Hedging	.06	97

8.3.1.5 Discussion and Results

The coyote scent survey of 1981 was conducted in October. The index of abundance was 40 (Table 8.3.1-1), which is the lowest index obtained over the past six years. During the past four years (1978-1981) coyote indices for Tract C-b have been lower than the average for the state of Colorado as reported by the U.S. Fish and Wildlife Service (Table 8.3.1-1). These low indices are perhaps due to increased local hunting.

8.3.1.6 Conclusions

The coyote index of abundance was 40 for 1981. Developmental activities on C-b Tract do not seem to be significantly affecting the coyote population in the study area.

8.3.2 Lagomorphs

8.3.2.1 Scope

Cottontails and jackrabbits provide a potentially important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b. At some time in the future, however, its status could change. The lagomorph relative-abundance estimates are based on data collected along the BA-designated transects. (See Exhibit C for transect locations and Volume 2 Appendix for identification of transects.)

8.3.2.2 Objectives

The objectives of lagomorph studies are to obtain relative-abundance estimates for cottontails and jackrabbits on and near Tract C-b.

8.3.2.3 Experimental Design

Relative abundance indices of cottontails and jackrabbits were estimated along the twenty-seven transects used for deer pellet group and browse production-utilization studies. Counts of presence-absence data were made inside the deer quadrats, but were restricted to an area of 0.001 acre.

8.3.2.4 Method of Analysis

Yearly differences and habitat affinity evaluations can be analyzed using t-tests. Trend analyses and correlations can be readily applied as well, but these analyses will be more appropriate after 3 or 4 more years of data are gathered.

8.3.2.5 Discussion and Results

Methods were perfected during this past year such that cottontail and jackrabbit pellets could be differentiated. Results of pellet counts conducted along 39 transects are shown in Table 8.3.2-1. No significant changes in abundance over the past two years was detected when

Table 8.3.1-1. Results of the coyote scent station survey, 1981.

Line	Location	No. of Stations	No. of Visits
1	Big Jimmy	25	0
2	Scandard Ridge	10	2
3	Scandard Gulch	10	0
4	SG-15	10	0
5	SG-3	10	0
6	Stewart Ridge	15	1
7	West Stewart Valley	10	0
8	Baily Ridge	10	1

$$\text{INDEX OF ABUNDANCE} = \frac{\text{No. of visits}}{\text{No. of stations}} \times 1000$$

$$= \frac{5}{100} \times 1000 = 40$$

INDICES OF ABUNDANCE FOR PREVIOUS YEARS:

Year	Tract C-b	USFWS (Colorado Average)
1974	188	98.1
1975	122	74.4
1976	Interim	110.2
1977	130	104.4
1978	50	104.4
1979	70	91.5
1980	50	82.2

Table 8.3.2-1. Relative abundance of cottontails and jackrabbits, 1980-81. Each transect consists of twenty 0.001 acre plots.

Transects	NUMBER OF PLOTS WITH LAGOMORPH DROPPINGS Cottontails	Jackrabbits
CHAINED RANGELAND:		
BA01	5	0
BA02	5	3
BA03	12	1
BA04	12	0
BA05	12	3
BA06	9	0
BA07	13	0
BA08	10	0
BA09	13	0
BA17	10	0
BA18	5	0
BA20	8	0
BA21	9	0
BA23	8	0
BA25	11	0
BA30	5	0
BA31	7	0
BA32	6	1
PINYON-JUNIPER:		
BA10	16	0
BA11	11	0
BA12	15	0
BA13	12	0
BA14	12	0
BA15	10	0
BA16	12	2
BA19	11	0
BA22	16	0
BA24	8	0
BA26	15	0
BA27	15	0
BRUSH-BEATEN SAGE:		
BA41	5	0
BA42	4	0
BA43	18	0
BA44	3	0
BA45	1	0
BA46	2	0
BA47	6	0
BA48	15	1
BA49	18	0

cottontail data for 1980-81 were compared with combined cottontail and jackrabbit data of 1979-80. Results of paired t-tests for chained and pinyon-juniper habitats respectively were $t = 1.95$, $df = 14$, $P>0.05$; and $t = 0.39$, $df = 11$, $P>0.50$. Because very few jackrabbit pellets were recorded in 1980-81, comparisons with combined cottontail and jackrabbit data of 1979-80 are believed valid. Higher counts of cottontail pellets were recorded in the pinyon-juniper habitat than in the chained habitat; the average number of quadrats with pellets were 12.8 and 9.5, respectively (number of quadrats per transect = 20). Differences were statistically significant ($t = 3.11$, $df = 25$, $P<0.005$).

8.3.2.6 Conclusions

Cottontail pellets were higher in the pinyon-juniper habitat than in the chained rangeland habitat. Lagomorph abundance does not seem to be significantly affected by the developmental activities in Tract C-b.

8.4 Small Mammals

8.4.1 Species Diversity and Abundance

8.4.1.1 Scope

Small mammals are important as prey species. Monitoring changes in selected population abundance parameters will aid in assessing potential effects of pollutants before populations of larger animals are greatly affected.

8.4.1.2 Objectives

The primary objective of small mammal studies during 1981 was to evaluate the effects of the water sprinkling program on abundance levels. Trapping was also undertaken as part of long-term trend studies.

8.4.1.3 Experimental Design

Methods designed to test the effects of watering chained rangeland habitat were as follows: Animals were captured using live traps, which were set out before watering occurred (June) and again after watering began (August). Trapping locations in treatment and control areas were chosen at random. Trapping locations in control areas were no more than one mile from the sprinkler system and were restricted to sites of similar habitat and topography. Linear transects of ten traps spaced 10m apart were positioned at each trapping location using a systematic sampling design. After each night of trapping, all transects were moved approximately 5 to 10m from the previous transect position. This procedure was followed to achieve independent samples, sample a larger area, and minimize recaptures. Moving transects a greater distance was not possible due to space limitations in the sprinkler area. An equal trapping effort (420 trap-nights) occurred in each area (treatment and control) and during each time period (June and August).

Trapping also occurred in pinyon-juniper habitat during June and August as part of long-term trend studies. Methods used in previous years were again employed.

8.4.1.4 Method of Analysis

The area-by-time interaction of a two-way ANOVA was used to test whether the watering of chained rangeland habitat caused changes in abundance of small mammals. Normality of the data was checked by plotting capture frequencies.

8.4.1.5 Discussion and Results

The water sprinkler program began in 1980 and preliminary small mammal studies were begun that year shortly after sprinkling began. The results of these studies were presented in last year's report. The conclusions made at that time were that deer mice and least chipmunks appear to avoid the watered areas and golden-mantled ground squirrels appear to be attracted to them.

During this past year, trapping occurred before as well as after watering in order to better evaluate the time factor. Results of the 1981 trapping effort (Table 8.4.1-1) suggest, unlike 1980 findings, that there is no attraction or avoidance by small mammals. Analyses were performed only for deer mice and least chipmunks, since other species were rarely captured; see Table 8.4.1-2 for a summary of all trapping results.

It is likely that the August trapping, which occurred only several weeks after watering, did not allow sufficient time for a behavioral response to occur. Conclusions, therefore, are tentative and further study is required.

8.4.1.6 Conclusions

1981 Trapping results show that there is no attraction or avoidance to the sprinkler area by small mammals.

8.5 Avifauna

A wide variety of birds exist on Tract C-b and in the surrounding area. Avifauna were monitored to determine potential effects of habitat disturbance on species abundance.

8.5.1 Songbird Relative Abundance and Species Composition

8.5.1.1 Scope

Songbirds were monitored during their breeding season to determine effects of development on avifauna. It is anticipated that habitat disturbance and increased human activity may effect population densities and relative abundance of the more prominent species. Certain species may be more affected by man-made impacts than others.

Table 8.4.1-1. Two-way analysis of variance tests on small mammal capture data. The analyses were designed to test for changes in small mammal abundance caused by watering of chained rangeland habitat.

TEST NO. 1. Deer Mice

Source of Variation	DF	MS	F	$F_{.05(1,164)}$
Between watered and control areas	1	0.38	0.2	3.90
Between June and August	1	3.43	2.2	
Area x Time interaction	1	2.88	1.8	
Error	164	1.57		

TEST NO. 2. Least Chipmunks

Source of Variation	DF	MS	F	$F_{.05(1,164)}$
Between watered and control areas	1	1.52	0.7	3.90
Between June and August	1	9.52	4.19**	
Area x Time interaction	1	0.38	0.17	
Error	164[1]	2.28		

Conclusion: the area-by-time interactions for both deer mice and chipmunks are nonsignificant. Therefore, no effects due to watering can be demonstrated. The significant F-test for chipmunk capture results suggests that June and August abundance levels were appreciably different (more captures occurred in June).

[1] Error degrees of freedom are based on n=42 in each 2x2 cell of the area-by-time analysis (a transect of 10 traps is considered one sample; 10x42 = 420 trap-nights for each cell).

** significant at $\alpha = 0.05$

Table 8.4.1-2. Relative abundance of small mammals, 1981[1]. Actual number of animals captured is shown in brackets.

	CHAINED RANGELAND				PINYON-JUNIPER	
	Area 1 (control site)		Area 2 (experimental site)			
			before watering	after watering		
Species	JUN (420)[2]	AUG (420)	JUN (420)	AUG (420)	JUN (150)	AUG (150)
Deer Mouse *Peromyscus maniculatus*	12.9 {54}	18.3 {77}	16.4 {69}	16.7 {70}	5.3 {8}	22.7 {34}
Least Chipmunk *Eutamias minimus*	26.9 {113}	23.1 {97}	29.8 {125}	24.0 {101}	2.0 {3}	
Uinta Chipmunk *Eutamias umbrinus*					14.7 {22}	10.0 {15}
Golden-mantled Ground Squirrel *Spermophilus lateralis*	0.7 {3}		4.8 {20}	0.7 {3}		
Apache Pocket Mouse *Perognathus apache*		0.5 {2}		0.2 {1}		
Desert Woodrat *Neotoma lepida*						3.3 {5}
Western Jumping Mouse *Zapus princeps*	0.2 {1}					

[1] Relative abundance = (number of capture ÷ number of trap-nights) x 100.

[2] Number of trap-nights (a trap-night is one trap set one night).

8.5.1.2 Objectives

Objectives of the program are to evaluate effects of development activity on songbird densities, species abundance and diversity by comparing control to developmental transect observations.

8.5.1.3 Experimental Design

Monitoring the avifauna transects occurs in May during the peak of the breeding season. Monitoring efforts are consistent with past sampling designs in that two transects in pinyon-juniper woodland and two transects in chained pinyon-juniper rangeland are sampled. One transect in each habitat type (Transects 1(BH01) and 4(BH04) are located in an area which will not be disturbed by oil shale development. The remaining three transects (Transects 2(BH02), 3(BH03), and 5(BH05) are located within each habitat where some disturbance from oil shale development is anticipated. All transects are 800 meters long and are permanently marked with steel rebar stakes and flagging. The method employed for censusing is the strip transect method as described by Emlen (1977) with slight modifications. This method provides data from which quantitive estimates of density of songbird-like species can be calculated.

8.5.1.4 Method of Analysis

The population density estimates for species observed on strip transects were determined by one of three methods described by Emlen (1971) which depended on the conspicuousness of the species to the observer. Since the validity of any of these methods varied for different species, professional judgment, based on experience with the conspicuousness of various species within different habitats during different seasons, was used in selecting the best density estimator. The Shannon-Weiner calculations (Pielou 1966) were used to compute indices of species diversity (H'), maximum diversity H'_{max})and equitability (J) for each habitat sampled by strip transect procedures. Symbols are defined in Table 8.5.1-1. The Hutchenson's t-test was used to test the null hypothesis that two sampled populations have the same diversity. The least squares linear regression model was used to determine if a linear trend exists for a set of observations.

Additional analysis included analyzing visual trends for species on transects and plotting species number by years and by transects.

8.5.1.5 Discussion and Results

See Table A.8.5.1-1 for a list of bird species observed on Tract C-b during the 1981 census period. Included in the table are species that were observed, but not included in the quantitative analysis because they were not observed during the census or because specific habits of species (i.e. American kestrel) rendered them unsuitable for this type of quantitative analysis.

The Shannon-Weiner diversity indices for the avifauna transects for 1977 thru 1981 are presented in Table 8.5.1-1. The diversity indices have remained fairly consistent over the years. However, all transects show lower diversities in 1981 than in 1980. Transect 4 showed the

TABLE 8.5.1-1

SHANNON-WEINER INDICES OF DIVERSITY

1977-1981

Transect	Vegetation Type	Year	$\hat{H}$	$\hat{H}$ Max	$\hat{J}$	E ($\hat{H}$)	Var ($\hat{H}$)
1	Chained Pinyon-Juniper Rangeland (Control)	1977	1.494	2.079	0.718	1.454	0.009
		1978	1.665	2.398	0.694	1.634	0.007
		1979	1.166	1.792	0.651	1.152	0.003
		1980	2.025	2.489	0.815	1.908	0.017
		1981	1.482	1.946	0.761	1.407	0.018
2	Pinyon-Juniper Woodland (Developmental)	1977	2.469	2.890	0.854	2.432	0.003
		1978	2.398	2.708	0.886	2.350	0.004
		1979	2.272	2.485	0.914	2.236	0.002
		1980	2.425	2.639	0.919	2.277	0.009
		1981	2.084	2.397	0.869	1.937	0.017
3	Chained-Juniper Rangeland (Developmental)	1977	1.950	2.197	0.888	1.895	0.004
		1978	1.885	2.398	0.786	1.868	0.003
		1979	1.526	1.946	0.784	1.508	0.003
		1980	2.271	2.708	0.839	2.143	0.015
		1981	1.599	2.197	0.728	1.491	0.026
4	Pinyon-Juniper Woodland (Control)	1977	2.740	2.944	0.931	2.709	0.001
		1978	2.545	2.890	0.881	2.522	0.002
		1979	2.189	2.398	0.913	2.168	0.002
		1980	2.463	2.944	0.837	2.329	0.014
		1981	2.307	2.639	0.874	2.177	0.011
5	Chained Pinyon-Juniper Rangeland (Irrigation Sprinkler System) (Control)	1980	2.197	2.639	0.832	2.034	0.020
		1981	1.595	2.079	0.767	1.512	0.018

NOTES:

(1) $\hat{H}$ is an estimate of H which is a measure of diversity developed by Shannon.

(2) $\hat{H}$ max is an estimate of H max which is a measure of the maximum possible diversity for a set of data consisting of k categories.

(3) $\hat{J}$ is an estimate of J which is termed evenness, homogeneity or relative diversity.

(4) E ($\hat{H}$) is the expectation of H.

(5) VAR ($\hat{H}$) is the variance of H.

(6) H is the population diversity, H Max is the population maximum diversity and J is the population

greatest H, H max, J, and E(H) while the least of these occurred on transect 1.

Relative abundance and species density for 1981 are similar to previous year's data (Tables 8.5.1-2, A8.5.1-2 thru A8.5.1-6). Species density for 1981 reached the lowest level for all transects since the transects were initiated in 1977. The most abundant species in the chained pinyon-juniper habitat type were the same as in 1980: Brewer's sparrow, green-tailed towhee, vesper sparrow, house wren, and mountain bluebird (listed in descending order). The most abundant species in the pinyon-juniper habitat were, in descending order, black-throated gray warbler, mountain chicadee, mountain bluebird, solitary vireo, and chipping sparrow. This is different from 1980 results where there were more mountain chicadees and fewer mountain bluebirds.

The time series analysis data for avifauna are shown in Table 8.5.1-3. Two possible trends were noted. One trend concerned the mourning dove population on transect two (see section 8.5.2.5). The second possible trend was a declining number of green-tailed towhees on transect 3. Comparing the green-tailed towhee from all the transects shows that the population fluctuates greatly. This variability, along with the fact that there were more green-tailed towhees on transect 3 this year than last year leads us to believe that the population is not on the decline. The transect will continue to be monitored to see if this trend continues.

The results for the Hutcheson's t-test are shown in Table 8.5.1-4. The null hypothesis, that there is no difference in population diversity of species between control and developmental transects, was tested. The null hypothesis was accepted for transects 1 vs 3 and 1 vs 5, but was rejected for 2 vs 4. Transects 2 and 4 are in the pinyon-juniper habitat. All the data were reviewed and no cause for the rejection of the null hypothesis could be found. There was no new development started which could have affected the avifauna transects. There are several possibilities for the null hypothesis being rejected. One is that there could be a one level error (error of the first level), which means the null hypothesis was rejected even though it was true. Second, the number of species on both transects have been varied over the years and with the lower diversities (on all transects) this year the differences may have been large enough to trigger a rejection. At this time there is not enough statistical evidence which shows any adverse affects of the developmental activity on avifauna over time. These transects will be monitored closely next year and if the Hutcheson's t-test gives the same indications then intensive monitoring may be initiated.

In addition to the avifauna studies, birds were casually monitored through the year. Mallards were again occasional visitors to our treatment ponds and the belt kingfisher was a common sight along Piceance Creek. A white-faced ivis was seen in one of the erosion control basins in May.

8.5.1.6 Conclusions

Brewer's sparrows, green-tailed towhees and vesper sparrows are still the most abundant species found in the chained pinyon-juniper habitat, while black-throated gray warblers, mountain chicadees

TABLE 8.5.1-2

Total Density Values for Avifauna Transects at C-b
During Spring Sample Period, 1977 - 1981

Transect	Vegetation Type	Year	Total Density/Ha
1 (BH01)	Chained Pinyon-Juniper Rangeland (Control)	1977	2.82
		1978	3.11
		1979	3.19
		1980	2.94
		1981	2.44
2 (BH02)	Pinyon-Juniper Woodland (Developmental)	1977	5.34
		1978	2.51
		1979	2.63
		1980	2.75
		1981	2.06
3 (BH03)	Chained-Juniper Rangeland (Developmental)	1977	3.51
		1978	4.90
		1979	3.00
		1980	3.44
		1981	2.32
4 (BH04)	Pinyon-Juniper Woodland (Control)	1977	7.4
		1978	4.82
		1979	3.70
		1980	4.19
		1981	3.19
5 (BH05)	Pinyon-Juniper Rangeland (Developmental-Sprinkler)	1980	2.51
		1981	2.63

TABLE 8.5.1-3

Time Series Analysis of Species on Avifauna Transects for 1977 - 1981

TRANSECT 1

SPECIES	NUMBER OF OBSERVATIONS	$\hat{\alpha}$	Accept Ho: ?	R^2	Intercept A	Slope b
BRSPAR	5	.7963	YES			
BTWARB	4	.7418	YES			
CHSPAR	3	.2123	YES			
*COFLIC	2	1.000	YES			
GTTOWH	5	.1942	YES			
HOWREN	3	.7579	YES			
MOBLUE	5	.1059	YES			
MODOVE	4	.5955	YES			
VESPAR	4	.3928	YES			

TRANSECT 2

SPECIES	NUMBER OF OBSERVATIONS	$\hat{\alpha}$	Accept Ho: ?	R^2	Intercept A	Slope b
BTWARB	5	.2308	YES			
CHSPAR	3	.0550	YES			
COFLIC	4	.2254	YES			
HOWREN	4	.7240	YES			
MOBLUE	5	.8240	YES			
MOCHIC	5	.1024	YES			
MODOVE	4	.0438	NO	.914286	85.25	-2.00
PINJAY	3	.6667	YES			
SOVIRE	5	.3474	YES			
VIWARB	4	1.0000	YES			
WBNUTH	4	.2254	YES			

TABLE 8.5.1-3 (Continued)

TRANSECT 3

SPECIES	NUMBER OF OBSERVATIONS	$\hat{a}$	Accept Ho: ?	R^2	Intercept A	Slope b
BRSPAR	5	.5015	YES			
CHSPAR	4	.7418	YES			
COFLIC	5	.1114	YES			
GTTOWH	5	.0467	NO	.78125	83.53125	-.26041667
HOWREN	4	.3292	YES			
MOBLUE	5	.4641	YES			
PINJAY	3	.2421	YES			
VESPAR	5	.4459	YES			

TRANSECT 4

SPECIES	NUMBER OF OBSERVATIONS	$\hat{a}$	Accept Ho: ?	R^2	Intercept A	Slope b
BRSPAR	3	.2123	YES			
BTWARB	5	.1450	YES			
CHSPAR	5	.0689	YES			
DUFLYC	3	.4246	YES			
GTTOWH	4	1.0000	YES			
HAWOOD	3	.8790	YES			
HETHRU	3	.3333	YES			
HOWREN	5	.2522	YES			
MOBLUE	5	.7022	YES			
MOCHIC	5	.2674	YES			
SOVIRE	5	.2007	YES			

* NOTE: No time series analysis when the number of observations is less than or equal to two. The model used was N = a+bt where a = intercept, b = slope, t = time and N is the predicted number of species. The set of hypotheses tested was

Ho: B = 0 (There Is No Trend)
Ha: B + 0 (There Is A Trend)

The α level used to test Ho was α = 0.05.
If $\hat{a} > \alpha$ accept Ho, otherwise reject Ho and accept Ha.

TABLE 8.5.1-4

HUTCHESON'S t-TEST FOR TESTING EQUAL POPULATION DIVERSITIES OF TRANSECTS FOR 1981

Transects To be Tested	Set of Hypotheses To be Tested	Variances of Diversities Associated With each Transect	Pooled Standard Deviation	Diversity Estimate for Each Transect	Calculation of Test Statistic t	Number of Observations in Each Transect	Degrees of Freedom	Critical Value t_{cr}	Accept Null Hypothesis
Transect 1	Ho: $H_1 = H_3$	$S^2_{H_1} = 0.01850$	$S_{H_1 - H_3} = 0.21183$	$H_1 = 1.4816$	$t = -0.55308$	$n_1 = 40$	$df_{1,3} = 74$	$t_{cr} = -1.293$	Yes
and									
Transect 3	Ha: $H_1 = H_3$	$S^2_{H_3} = 0.02637$		$H_3 = 1.59876$		$n_3 = 37$			
Transect 1	Ho: $H_1 = H_5$	$S^2_{H_1} = 0.01850$	$S_{H_1 - H_5} = 0.19049$	$H_1 = 1.4816$	$t = 0.59688$	$n_1 = 40$	$df_{1,5} = 81$	$t_{cr} = -1.292$	Yes
and									
Transect 5	Ha: $H_1 = H_5$	$S^2_{H_5} = 0.01779$		$H_5 = 1.5953$		$n_5 = 42$			
Transect 2	Ho: $H_2 = H_4$	$S^2_{H_2} = 0.01717$	$S_{H_2 - H_4} = 0.1675$	$H_2 = 2.0844$	$t = -1.3313$	$n_2 = 34$	$df_{2,4} = 71$	$t_{cr} = -1.2935$	No
and									
Transect 4	Ha: $H_2 = H_4$	$S^2_{H_4} = 0.01083$		$H_4 = 2.3074$		$n_4 = 50$			

NOTES:

1. Selected $\alpha = 0.20$ as defined for Songbird relative abundance and specie composition, Section 8.5.1 in DMP dated February 23, 1979.
2. $t_{cr} = t_{\alpha/2,\, df}$
3. If $t \leq |t_c|$ Accept Ho, otherwise reject Ho.
4. All subscripts correspond to transect numbers.

and mountain bluebirds dominate the pinyon-juniper avifauna studies. Based on the data collected on C-b Tract, developmental activities have not caused any significant changes in songbird diversity or density in the study areas.

8.5.2 Upland Gamebirds - Mourning Dove Relative Abundance

8.5.2.1 Scope

The mourning dove is the only upland gamebird present in sufficient numbers to be monitored. Field observations during the baseline data accumulation program indicated that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable monitoring program for them can be designed to determine changes over time; thus, a monitoring program for them is not warranted.

8.5.2.2 Objectives

The objective was to monitor the mourning dove populations to see if development of Tract C-b has affected their relative abundance.

8.5.2.3 Experimental Design

Methods used were identical to those used for songbirds. Throughout the year gamebirds observed were recorded on Wildlife Observation Reports.

8.5.2.4 Method of Analysis

The data were analyzed in the identical manner described for analyzing the relative abundance for the songbird-like population parameter.

8.5.2.5 Discussion and Results

Mourning dove data from the 1977-1981 avifauna studies are presented in Table 8.5.2-1. The mourning dove population continues to show fluctuations in size and distribution without any definable patterns. Time series analysis (Table 8.5.1-3) notes a possible trend on transect 2. Mourning doves seem to be declining. However, the largest number of mourning doves found on transect 2 were only four, with the lowest being two. This population sample is too small to establish a trend to date. Also, transect 2 was the only transect that mourning doves were found on during the 1981 sampling period.

In addition to the mourning doves, two sage grouse were sighted in November just north of the C-b security gate.

8.5.2.6 Conclusions

The mourning dove population does not seem to be affected by the developmental activities on C-b Tract. The mourning dove population continues to fluctuate yearly without any definable patterns.

TABLE 8.5.2-1

Mourning Dove Estimates at Tract C-b for Spring Sampling Periods, 1977-81

Transect	Date	Observations	Coefficient Detectability	Density /Ha	% Relative Abundance
Chained Pinyon-Juniper (BH01)	1977	2	1.00	.03	2.5
	1978	1	1.00	.02	0.9
	1979	1	1.00	.04	1.2
	1980	3	1.00	.19	6.4
	1981	0	1.00	.00	0.0
Pinyon-Juniper (BH02)	1977	4	1.00	.07	1.7
	1978	0	0.74	.00	0.0
	1979	3	0.74	.14	5.2
	1980	3	0.74	.19	6.84
	1981	2	0.74	.125	6.06
Chained Pinyon-Juniper (BH03)	1977	2	1.00	.03	2.1
	1978	0	1.00	.00	0.0
	1979	0	1.00	.00	0.0
	1980	0	1.00	.00	0.0
	1981	0	1.00	.00	0.0
Pinyon-Juniper (BH04)	1977	17	1.00	.29	5.9
	1978	5	0.74	.17	4.2
	1979	0	0.74	.00	0.0
	1980	0	0.74	.00	0.0
	1981	0	0.74	.00	0.0
Sprinkler Area (BH05)	1980	0	0.74	.00	0.0
	1981	0	0.74	.00	0.0

8.5.3 Raptor Activity

8.5.3.1 Scope

Raptor activity was monitored on Tract C-b on a continuing basis because of the importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

8.5.3.2 Objectives

The main objective of raptor monitoring was to detect changes in raptor utilization on or near Tract C-b.

8.5.3.3 Experimental Design

Trends in utilization of Tract C-b and immediately contiguous habitats by raptors were established for the breeding season by determining the percent of known nest sites which were occupied by nesting pairs and comparing these data with data obtained during the baseline period and following years. Nest occupancy checks were made annually during April (great-horned owls, ravens, red-tailed hawks) and June (red-tailed hawks, eagles, great-horned owls). Throughout the year, any raptor sightings by the field biologists within the study boundary were recorded.

8.5.3.4 Methods of Analysis

Data analysis of nest occupancy was by professional judgement.

8.5.3.5 Discussion and Results

The raptor nesting records for 1976 through 1981 are listed in Table 8.5.3-1. In April there were eight nests that had signs of activity. Red-tailed hawks occupied five of those nests, ravens two of the nests and a golden eagle was active around one nest. There were also eight active nests during the June census period. Seven nests were occupied by red-tailed hawks and one nest by ravens. The golden eagle seen during the April census was not seen during the June census period. A total of ten young red-tailed hawks was produced from all the nests studied.

In addition to the nesting raptors, other raptors observed in the study area included: great-horned owl, American kestrel, common night-hawk, marsh hawk, rough-legged hawk, Swainson's hawk, turkey vulture and bald eagle.

The raptor population is fairly stable in the study area. Our nesting population of raptors is composed largely of red-tailed hawks which is consistent with past years' nesting records.

8.5.3.6 Conclusions

Developmental activities on the C-b Tract seem to be having little effect on the raptor activity in the area.

TABLE 8.5.3-1 RAPTOR NESTING RECORD

Nest No.	Species	Status 1976 April	Status 1976 June	Status 1977 April	Status 1977 June	Status 1978 April	Status 1978 June	Status 1979 April	Status 1979 June	Status 1980 April	Status 1980 June	Status 1981 April	Status 1981 June
1	Unknown	I		I	I	I	I	I	I	I	I	I	I
2	Unknown	I		I	I	I	I	I	I	I	I	I	I
3	Unknown	I		I	I	I	I	I	I	I	I	Nest Gone	
4	Red-tailed Hawk	E or Y		I	I	I	I	I	I	I	I	I	I
5	Unknown	I		I	I	I	I	I	I	I	I	I	I
5a	Common Raven	-		-	E or Y	I	I	I	I	I	I	A	I
6	Golden Eagle	E		I	2Y	I	I	E or Y	I	1Y	1Y	E	I
7	Red-tailed Hawk	I		I	-	E	I	E or Y	I	E or Y	1Y	E	2Y
8	Red-tailed Hawk	4Y		I	I	E	I	E or Y	I	I	I	I	I
9	Common Raven	I		I	I	I	I	I	I	E	2Y	I	I
10	Red-tailed Hawk	I		I	I	I	I	I	I	I	I	I	I
11	Nest Gone												
12	Red-tailed Hawk	I		I	I	E	1Y	I	I	I	I	I	I
13	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	I	I	I
14	Unknown	I		I	I	I	I	I	I	I	I	I	I
15	Unknown	I		I	I	I	I	I	I	I	I	I	I
16	Great Horned Owl	I		I	I	E	2Y	I	I	I	I	I	I
17	Great Horned Owl	I		I	I	I	I	I	I	I	I	I	I
18	Red-tailed Hawk	I		I	I	I	I	1Y	I(GHO)	I	I	I	I
19	Great Horned Owl	1Y		I	I	I	I	I	I	I	I	I	I
20	Unknown							I	I	Packrats			
21	Not on map												
22	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	2Y	A	I
23	Not on map												
24	Red-tailed Hawk	I		I	I	I	I	I	I	Packrats		E	(?)Y
25	Great Horned Owl	I		I	I	I	I	I	I	Packrats			
26	Unknown	I		I	I	I	I			Nest Gone			
27	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	I	E	1Y
28	Golden Eagle	1Y		I	I	I	I	I	I	I	I	I	I
29	Unknown	I		I	I	I	I	I	I	I	I	I	I
30	Red-tailed Hawk	2Y		I	I	I	I	I	I	I	I	I	I
31	Unknown	I		I	I	I	I	I	I	I	2Y(RTH)	I	I
32	Great Horned Owl	2Y		2Y	-	I	I	I	I	I	I	I	2Y(RTH)
33	Unknown	I		I	I	I	I	I	I	I	I	I	2Y(RTH)
34	Unknown	I		I	I	I	I	I	I	I	I	I	I
35	Unknown	I		I	I	I	I	I	I	I	I	I	I
36	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	I	I	I	I
37	Unknown	I		I	I	I	I	I	I	I	I	I	I
38	Raven	I		I	I	I	I	E or Y	Y	I	E or Y	A	A
39	Golden Eagle	1Y		I	I	I	I	I	I	I	I	I	I
40	Great Horned Owl	I		I	I	E	2Y	2Y	I	I	I	I	I
41	Unknown	I		I	I	I	I			Nest Gone			
42	Unknown	I		I	I	I	I	I	I	I	I	I	I
42a	Red-tailed Hawk	-		-	2Y	I	I	E or Y	I(GHO)	I	I	I	I
43	Great Horned Owl	2Y		I	I	I	I	I	I	I	I	I	I
44	Unknown	I		I	I	I	I	I	I	I	I	I	I
45	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	I	2Y	I	I
46	Red-tailed Hawk					E	I	E or Y	I	I	I	I	I
47	Unknown					I		I	I	I	I	I	I
48	Great Horned Owl							E	I	I	I	E(RTH)	1Y
49	Red-tailed Hawk							E	I	I	I	I	I
50	Magpie									I	I	I	I
51	Red-tailed Hawk									I	1Y	I	I
*52	Red-tailed Hawk									I	I	I	1Y
	TOTAL ACTIVE NESTS	11		4		6		15		8		8	

Code:

I = inactive nest
A = signs of activity (ex. fresh boughs, bird near nest)
E = adult bird observed in an incubating posture; presumed to be incubating eggs.
(2) Y = number of young observed in the nest.
E or Y = adult bird observed in an incubating posture; due to time of year, assumed to be either incubating eggs or brooding very young chicks.
* = new nest

8.6 Aquatic Ecology

8.6.1 Benthos

8.6.1.1 Introduction and Scope

The benthic macroinvertebrate community is an important component of the stream ecosystem. These organisms process and convert organic material into animal tissue, which is thereby available to higher tropic levels such as insectivorous fishes. For some time, macroinvertebrates have been recognized as valuable indicators of water quality (Kolkowitz and Marsson (1909); Hynes (1970); Cairns and Dickson (1973).

8.6.1.2 Objectives

The purpose of this investigation is to infer water quality and bioproductivity from macroinvertebrate taxa present. Data collected on benthos taxonomic composition, relative abundance, and diversity at all sampling stations permit the evaluation of effects of development activity on benthos as well as identification of potential impacts on other components of the aquatic system.

8.6.1.3 Experimental Design

Benthic macroinvertebrate sampling stations are located at three sites along Piceance Creek (Figure 8.6.1-1). These sites are listed as WP01 (Stewart Gulch near USGS Station WU07), WP02 (Middle Station), and WP03 (Hunter Creek near USGS Station WU61) and are described in Table 8.6.1-1. Station WP01 was moved in 1977 from a baseline location of P-1 farther upstream to its current position as a control station above development impact. Table 8.6.2-1 in the 1979 C.B. Annual Report provides a cross reference to the station codes.

A standard Surber sampler was used to obtain three replicate benthic samples from each station at approximately one month intervals from May 28 to November 4, 1981 (6 sample periods). Each replicate was placed in a labeled container and preserved with 10% formalin in the field. The samples were shipped to Mariah Associates' Aquatics Laboratoy in Laramie, Wyoming for further processing and analysis.

In the lab, the samples were washed over a fine mesh sieve (U.S. No. 60). Organisms were separated from debris and placed in vials of 95% ethanol. Identification and enumeration were accomplished with the aid of a Stereo dissecting microscope (10x-40x). Whole oligochaete and chironomid head capsules were mounted in glycerin or Canada balsam and identified with the use of a compound microscope at magnifications of up to 400x.

Identification of organisms were based primarily upon Usinger (1956), Edmondson (1959), Wiggins (1977), Edmunds et al. (1976), Baumann et al. (1977), and Pennak (1978). Organisms were identified to the lowest practical taxon. To ensure the accuracy of benthic identifications, taxa not previously identified by Mariah Associates and a random selection of

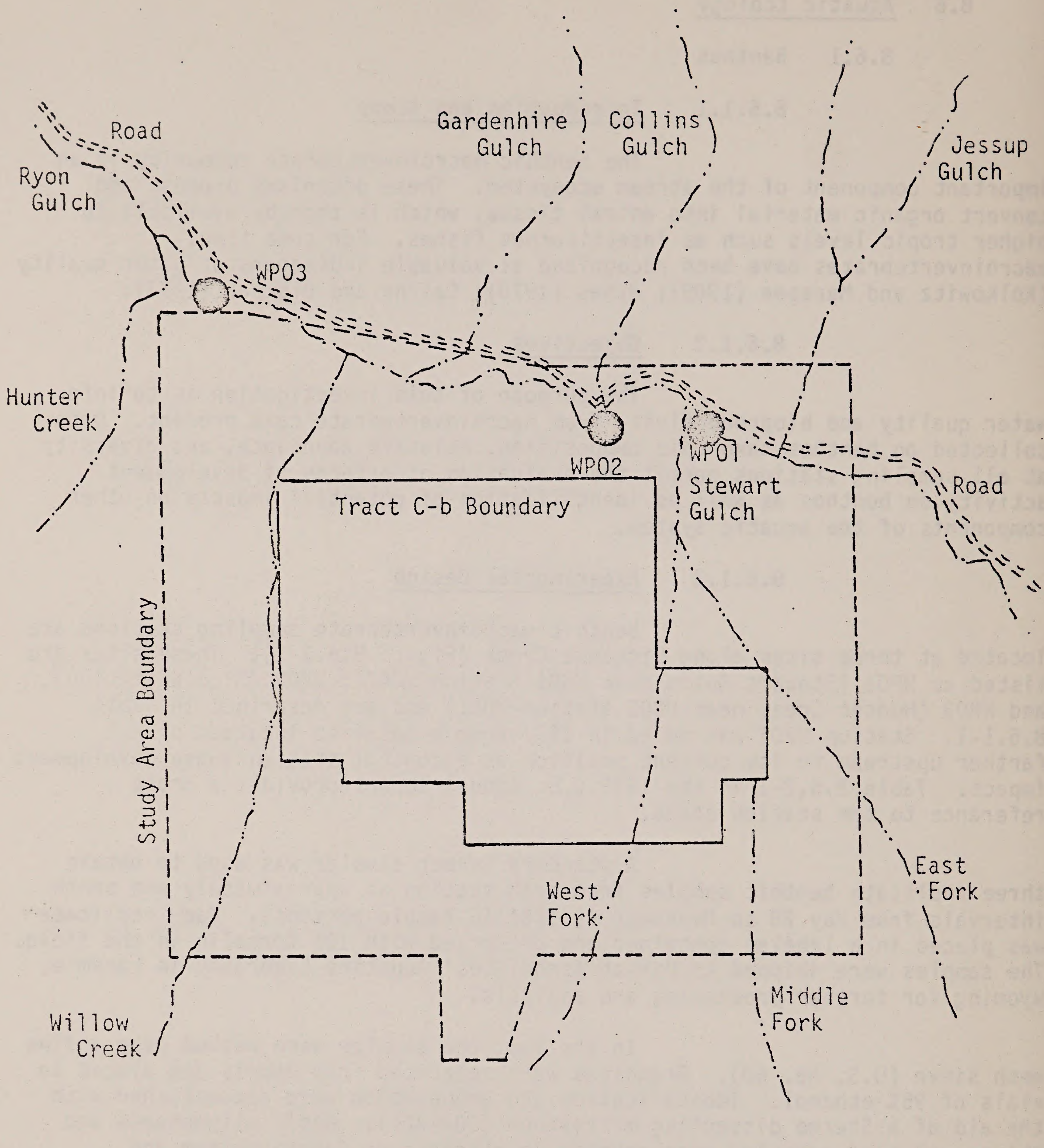


FIGURE 8.6.1-1

BENTHIC MACROINVERTEBRATE AND PERIPHYTON SAMPLING STATIONS

TABLE 8.6.1-1

DESCRIPTION OF MACROINVERTEGRATE SAMPLING SITES ON PICEANCE CREEK, MAY 1981

Sample Station Location	Creek	Site Description	Substrate Type[1/]	Mean Depth (in)[2/]
Stewart Station	Piceance	Grass/low shrub/pasture	30% rubble 50% gravel 20% silt and sand	8
Middle Station	Piceance	Grass/low shrub/pasture Small waterfall at upper end of station; major irrigation diversion above small waterfall	40% rubble 40% gravel 20% silt and sand	5
Hunter Station	Piceance	Grass/low shrub/pasture	10% rubble 50% gravel 40% silt and sand	8

1/ Rubble (64-256 mm); Gravel (2-64 mm); Sand (0.06-2.0 mm); Silt (0.004-0.6 mm) (Adapted from Cummins (1962)

2/ Mean Depths shown were approximately minimum depths for 1981 season due to high rainfall. Flow rates at all stations were more constant than last year.

10% of the remaining taxa were sent to qualified professionals for independent confirmation.

8.6.1.4 Methods of Analysis

By comparing seasonal trends from 1981 to previous years, it may be possible to elucidate the effects of the C.B. Shale Oil Project upon the benthic fauna of Piceance Creek. To aid in this comparison, the following data were calculated for each sample station during each sample period:

1. Taxonomic identification
2. Density (organisms/m2)
3. Relative abundance
4. Shannon-Weiner diversity index
5. Maximum diversity
6. Evenness
7. Analysis of variance

Density (and relative abundance) estimates derive directly from the counts of organisms in each Surber sample since the area of the sample is known.

The diversity index used is based on the Shannon-Weiner function from the field of information theory (Margalef (1967); Lloyd and Ghelardi (1964); Pielou associated with benthos counts. Descriptions of these methods are found in Snedecor and Cochran (1967) and Elliott (1977). Duncan's new multiple range test was used in multiple comparisons (Ott (1977).

8.6.1.5 Discussion and Results

Forty-four taxa were collected and identified during the 1981 study period. Computer data listings for each sample station with density, relative abundance indices, and Shannon-Weiner diversity indices a listing of taxa found at each station during 1981 and a listing of taxa found during each sample period at each of the three stations were presented in Tract C-b Development Monitoring Report #7, Volume 3, Section 2.5.2 (Aquatic Studies). Shannon-Wiener diversity indices, estimates of evenness, and the number of taxa obtained per station for each sample period are summarized in Table 8.6.1-2. Similarly, mean densities are summarized in Table 8.6.1-3.

During the 1981 monitoring study, samples from Stewart Station consistently contained greater numbers of total taxa than either of the two downstream stations. No consistent patterns involving diversity or evenness was evident. The macroinvertebrate community of Piceance Creek is generally low in number of species and reflects the harsh physical environment common to streams in the Piceance Basin of Colorado (Gray and Ward (1978).

Diptera was the most abundant ordinal level taxon over the course of 1981 at Stewart Station; Haplotaxida dominated the benthic faunal communities at Middle and Hunter Stations although Dipterans were still highly abundant at these sites (Table 8.6.1-4). Ephemeroptera were abundant at both Stewart and Hunter Stations, but this order was represented by

TABLE 8.6.1-2

SHANNON-WEINER DIVERSITY (H'), EVENNESS (E), AND TOTAL NUMBER OF TAXA (N) IN BENTHIC MACROINVERTEBRATE SAMPLES COLLECTED FROM PICEANCE CREEK, MAY THROUGH NOVEMBER 1981, TRACT C-b

Sample Date	Stewart Station			Middle Station			Hunter Station		
	H'	E	N	H'	E	N	H'	E	N
May 28	0.72	0.23	22	1.32	0.44	20	1.64	0.61	15
June 30	1.36	0.49	16	0.15	0.07	11	0.47	0.18	14
July 30	2.16	0.75	18	1.10	0.42	14	2.18	0.51	12
August 31	1.37	0.52	14	0.14	0.07	7	1.42	0.57	12
September 30	2.10	0.67	23	1.34	0.46	18	1.10	0.50	9
November 4	1.52	0.49	22	1.20	0.44	15	0.75	0.29	13

TABLE 8.6.1-3

MEAN DENSITIES (organisms/m^2) OF BENTHIC MACROINVERTEGRATE SAMPLES COLLECTED FROM PICEANCE CREEK MAY THROUGH NOVEMBER 1981, TRACT C-b

Date	Stewart Station	Middle Station	Hunter Station
May 28	8780.1	8780.1	11008.3
June 30	1524.9	8421.2	5177.6
July 30	1176.9	5766.1	1252.2
August 31	617.2	3171.9	685.3
September 30	3186.2	6516.0	3265.2
November 4	5436.0	8098.3	2059.6

TABLE 8.6.1-4

AVERAGE PERCENT RELATIVE ABUNDANCE OF BENTHIC FAUNA IN PICEANCE CREEK, 1981
(values rounded to the nearest percent)

Taxon	Stewart Station	Middle Station	Hunter Station
Phylum Nematoda	1	1	+1/
Order Haplotaxida	29	70	55
Order Amphiphoda	+	+	+
Order Acarina	+	-2/	-
Order Ephemeroptera	10	2	10
Order Plecoptera	1	1	+
Order Coleoptera	4	1	1
Order Trichoptera	2	1	+
Order Diptera	50	23	32
Order Bassopmatophora	4	1	3
Order Heterodonta	+	-	-

1/ + : Present at less than 1%

2/ - : Absent

only relatively low numbers at Middle Station. A similar spatial pattern of relative abundance was observed in the Bassomatophora. The numbers of Coleoptera decreased downstream from Stewart Station, and the same occurred in the Trichoptera and Plecoptera but to a less discernible degree.

Fifteen taxa were encountered in 1981 which were not observed in 1980 (Table 8.6.1-5). Of these taxa, six were not reported by Gray and Ward (1978). Only four of the taxa found in Piceance Creek in 1980 were not encountered in 1981.

In 1981, all three stations monitored on Piceance Creek had peak macroinvertebrate densities in May and lowest densities in August. Such a correlation of benthos densities between stations was not observed in 1980 when each station was at peak density on a different sampling date.

The results of the 2x3x6 analysis of variance of macroinvertebrate densities from 1980 to 1981 indicate a highly significant ($p<0.01$) three-way interaction term. Therefore, an external factor is having a disproportionate influence among stations during the sampling season and between years. This could be the result of either natural or development-induced variations in the hydrology or hydrochemistry of Piceance Creek, occurring temporally and spatially. Benthic fauna densities in the section of Piceance Creek under study were much higher in 1981 (2924 individuals/m^2) than they were in 1980 (382 individuals/m^2). During the last two years of monitoring, Middle Station has had significantly greater densities (1762 individuals/m^2) than either Stewart or Hunter Stations (815 and 824 individuals/m^2, respectively).

In order to evaluate whether Tract C-b development may have been responsible for the apparent disruption of the benthic fauna, the results of this investigation were compared to previous studies of the Piceance Creek. The 1974-1976 C-b baseline study (C-b Annual Report 1977), as well as the study by Gray and Ward (1978), provide site-specific pre-development data which may be compared to current results. While their data are not in a form allowing statistical comparison to the 1980 and 1981 data, comparisons of general trends in taxonomic composition and density are possible. Strict comparisons of diversity indices from previous years are not possible due to differences in taxonomic levels of identification used.

Thirty-eight taxa were collected from Stewart Station in 1981 compared to 28 in 1980. Diptera was the most abundant order in May 1981 with Chironomids of the tribes Orthocladiini and Metriocnemiini accounting for 86% of the relative abundance of the benthic fauna at this time. In June, the Diptera and the Haplotaxida were almost equally abundant at Stewart Station. Ephemeroptera dominated the July samples, while Haplotaxida were abundant in August and Diptera were dominant in both September and November. These results are somewhat different from the results of the 1980 study where Ephemeroptera was the dominant order in May, June, and late September; Diptera dominated in early August (corresponding to the July 1981 sampling period); and Trichoptera was the major taxon during the last sampling period of 1980. The only period for which the major taxon was the same in 1980 and 1981 at Stewart Station was the late August-early September period during

TABLE 8.6.1-5

BENTHIC MACROINVERTEGRATE TAXA ENCOUNTERED IN 1981 BUT NOT IN 1980; AND THOSE ENCOUNTERED IN 1980 BUT ABSENT FROM THE 1981 LIST

Taxa Present in 1981 but not in 1980	Taxa Absent in 1981 but Present in 1980
_Hyalella azteca_*	Collembola
Gammarus lacustris	Chloroperlidae
Acarina	_Chrysops_
_Ephemerella (Serratella)_*	_Lymnaea_
_Choroterpes_*	
_Heliophorus_*	
Oreodytes and _Deronectes_	
Prodiamesini	
Pentaneurini	
Macropelopiini*	
Dolichopodidae	
Empididae	
Dicranota	
Pisidium	

* Not reported by Gray and Ward (1978)

which the oligochaete order, Haplotaxida, predominated in both instances. For the 1981 study period as a whole, the three most dominant orders and their mean relative abundances were Diptera (50%), Haplotaxida (20%), and Ephemeroptera (10%) compared to the overall mean values from 1980 of 34%, 18%, and 34%, respectively.

During the 1974 through 1976 baseline study in the vicinity of Stewart Station, Ephemeroptera comprised 20% of the fauna, Diptera 32%, and Haplotaxida 43%. From August 1975 to July 1976, Gray and Ward (1978) found Ephemeroptera to be 36% of the fauna at a Piceance Creek site just upstream from Stewart Station. Diptera and Haplotaxida comprised 16% and 34% of the fauna, respectively,. From August 1976 to April 1977, Ephemeroptera were 30% of the fauna, Diptera 12%, and Haplotaxida 40% (Gray and Ward (1978).

In 1981, 31 taxa were collected from Middle Station compared to 36 in 1980. Of this total, the Oligochaete family, Tubificidae, was collected on every sampling date, and Haplotaxida was the most abundant order during each period except for May when the Diptera predominated. In 1980, the oligochaetes were dominant only in May and late September, while dipterans dominated the remaining periods. During 1981 overall, the three major orders represented at Middle Station and their mean relative abundances were Haplotaxida (70%), Diptera (23%), and Ephemeroptera (2%). In 1980, the respective values were 36%, 44%, and 6%, respectively.

Macroinvertebrates were not sampled at Middle Station prior to 1980. In 1981, 27 taxa were encountered at Hunter Station while the 1980 monitoring study yielded only 22. The May and September 1981 samples were dominated by Diptera, while Haplotaxida was the major order on the remaining sampling dates. In 1980, Haplotaxida was the dominant order in all but the late October samples when the Diptera were most abundant. The average relative abundances for the three major orders of benthic macroinvertebrates at Hunter Station in 1981 were Haplotaxida (55%), (32%), and Ephemeroptera (10%). In 1980, these values were 58%, 29%, and 12%, respectively.

During baseline studies (1974 through 1976), Haplotaxida were 47%, Ephemeroptera 20%, and Diptera 29% of the fauna at Hunter Station. Gray and Ward (1978) had a sampling site located near Hunter Station. At this site, Haplotaxida were 34% of the fauna between August 1975 and July 1976, and 59% between August 1976 and April 1977. Similarly, the Ephemeroptera were 46% and 10%, while the Diptera were 18% and 27%, respectively. Taxonomic composition of the benthic fauna in 1981 varied only slightly from previous studies. Comparisons must be made with caution because factors such as station location, time of sampling, length of sampling season, and taxonomic level of identification have not been kept constant from year to year. No major changes in the benthos of Piceance Creek in the area of Tract C-b have occurred since the baseline study. The dominant taxa have consistently been reported to be the oligochaete order, Haplotaxida, and the insect orders, Diptera and Ephemeroptera.

Gray and Ward (1978) reported that density, diversity and biomass decreased from upstream to downstream. They also attributed the differences between stations to the influence of agriculture (irrigation withdrawals), spring-fed tributaries and ground water inflow. Data for 1981 tend to confirm their findings. Comparisons of 1980 and 1981 data,

alone, demonstrate that the macroinvertegrate densities, along with the numbers and kinds of taxa present in Piceance Creek, undergo significant variations from year to year. However, the increases in relative abundance of the Oligochaeta at Middle and Hunter Stations in 1980 and 1981 may indicate an increase in siltation at these locations.

8.6.1.6 Conclusions

A multitude of factors such as irrigation, cattle grazing, springs, and Tract C-b water discharge may affect Piceance Creek aquatic systems. While the 1981 study showed no large changes in the benthic fauna of Piceance Creek, macroinvertebrate data do show an increase in relative abundance of the Oligochaeta at the two downstrean stations with respect to the control (Stewart) station. Comparisons to previous studies, including the baseline conditions, appear to rule out Tract C-b discharge as being a major reason for this difference. The changes observed seem to be attributable primarily to agricultural impacts and natural variations.

8.6.2 Periphyton

8.6.2.1 Introduction and Scope

Sensitivity of periphyton to changes in their environment has been well documented (Cholnoky (1968); Lowe (1974); Whitton (1975); Patrick (1977). Species composition and relative abundance of the total periphyton community and key periphyton species can provide good indicators of potential project effects on Tract C-b vicinity aquatic systems. Not only are periphyton amenable to sampling techniques which provide a good quantitative data base for identifying changes quickly and accurately, but they are also attached forms which cannot swim away from an adverse situation and return when conditions become more suitable for their existence. Many algal generation times are measured in hours or days rather than months or years. Thus, algae are very sensitive to changes in their environment and provide important information for evaluating the potential effects of Tract C-b development on Piceance Creek biota.

8.6.2.2 Objectives

The purpose of this investigation is to infer changes in water quality by examining algal bioproductivity. Data collected on periphyton species composition, relative abundance, diversity, and biomass at all sampling stations permit the evaluation of effects of development activity on periphyton communities as well as identification of potential impacts on other components of the aquatic system.

8.6.2.3 Experimental Design

The 1981 periphyton sampling stations located in Piceance Creek are identified on Figure 8.6.1-1 and described in Table 8.6.1-1. Periphyton were collected from artificial substrates (glass slides) at each station during six sampling periods in 1981 (at approximately one-month intervals from May 28 to October 29). The glass slides were incubated in the water for at least 29 days. Nine slides were collected from each station,

placed in individual cytomailers and preserved with 4% formalin. Three of the nine slides were used for toxonomic identification and enumeration, three for biomass determinations, and three were extra slides in case any of the others became damaged. The cytomailers were sent to Mariah Associates' Aquatic Laboratory in Laramie, Wyoming for analysis.

8.6.2.4 Method of Analysis

The following data were derived:

1. Species identification
2. Total taxa by sample and station
3. Density (organisms/mm^2)
4. Relative abundance
5. Biomass (mg/cm^2) per sample
6. Shannon-Weiner diversity index
7. Maximum index
8. Evenness
9. Analysis of variance

Species identification, density, and relative abundance were estimated using the procedure described below. Algae other than diatoms were identified directly from the slides with 200x or 400x magnification. The periphyton were then scraped from each slide with a razor blade and placed into separate jars. The content of each jar was standardized at a volume of 100 ml by the addition of distilled water when necessary, after which it was thoroughly mixed in a blender for one minute. A single 1 ml aliquot was removed from each jar and diluted to a known volume with distilled water. A second 1 ml aliquot was withdrawn from the diluted subsample and placed in a Sedgwick-Rafter counting cell. With a 20x objective, the numbers of organisms were counted in a minimum of two lengthwise strips. The total number of diatoms was determined without identification to the generic or species level. Counts were also completed for the remaining individuals representing other algal divisions. Colonies and each 50 m filament section were considered as single units. The quantitative determination obtained with this method was then expressed as:

$$\text{No. Cells/mm}^2 = \frac{C \times 1000\ \text{mm}^2 \times V \times DF}{L \times W \times D \times S \times A}$$

where: C = number of cells counted (tally)

V = sample volume, ml

DF = dilutaion factor

L = length of strip, mm

W = width of a strip (Whipple grid image width), mm

D = depth of a strip (S-R cell depth), mm

S = number of strips counted

A = area of substrate scraped, mm^2 (Weber (1973)

To identify a diatom species and its relative abundance within the diatom flora, 10 ml were removed from the initial blended sample and centrifuged at 3000 rpm for 20 minutes. The supernatant was removed and the pellet resuspended in 30% hydrogen peroxide for a minimum of three days while the organic matter was oxidized. This mixture was centrifuged again for 20 minutes and the pellet resuspended in distilled water. Several drops of the second resulting mixture were placed with a pipet on a No. 1 25 mm^2 cover glass. The sample was dried on a hot plate at 95°C. As soon as the sample was dry, the temperature of the hot plate was increased to 100°C in order to drive off all remaining organic matter. A labeled microscope slide was placed on a moderately warm hot plate, and a drop of Hyrax Mounting Medium added to the center of the slide. The cover glass was then placed face-down on the drop of Hyrax. After the toluene evaporated from the Hyrax, the slide was removed from the hot plate and allowed to cool. Identification and relative abundance of diatoms were then determined with the use of an oil immersion objective. Counting was stopped when a minimum of 100 individuals of the most common diatom was attained. The total number of diatoms as well as the number of each diatom species was used to calculate relative abundance. The percent composition of every diatom species was multiplied by the total diatom density determined in the Sedgwick-Rafter count to yield the density of each of these species (Weber (1973).

To estimate biomass, periphyton material was removed from the slides with a razor blade, and the scrapings placed in separate crucibles to be dehydrated in a drying oven at 105 to 110°C. Samples were then cooled to room temperature in a dessicator and weighed to the nearest 0.0001 g (gross dry weight). After ashing in a muffle furnace at 450°C for approximately four hours, the samples were rewet upon cooling to replace their water of hydration, redried to a constant weight at 105 to 110°C, and weighed to the nearest 0.0001 g (gross ash weight). Ash-free dry weight was obtained by subtracting gross ash weight from gross dry weight since the evaporating dish tare was assumed to be identical for the two weights. Ash-free weight biomass was then calculated according to the following equation:

$$\text{biomass (mg/cm}^2) = \frac{Wd - Wa}{As}$$

where: Wd = dry weight plus tare, mg

Wa = ash weight plus tare, mg

As = area scraped from slide, cm^2

The Shannon-Weiner index along with the actual number of species observed is the most useful measure of diversity (Hutchinson (1975). Methods for calculating the Shannon-Weiner index, the maximum index, and the Evenness are provided in Section 8.6.1.4. The relative abundance of certain indicator species may disclose the potential impact of oil shale development on the periphyton community. In this analysis, the following hypotheses are tested:

H_0 = No significant change exists in the periphyton communities over time,

H_0 = No significant difference exists in the periphyton communities at the control station vs the development stations from baseline data, recognizing the differences during baseline.

Analysis of variance was used to compare periphyton data collected at different stations during 1981 and to compare 1981 data with data from previous samples. The data were $\log_{10}$ transformed to reduce inequality of variance within samples. In many cases, especially with biological data, without a transformation there is too much within sample variability which leads to a loss of power to test various hypotheses (Elliott (1977). Bartlett's test of inequality of variance is used to determine whether the transformation is successful. A factorial design (Snedecor and Cochran (1967); Weber (1973) is used to detect any impact possibly caused by oil shale development. Although the factorial analysis of variance is able to detect changes even though differences existed before any developmental impact, it is unable to separate two different impacts. Therefore, a significant difference is based on statistical analysis and professional judgement. When a significant difference was determined to exist, the water collected on the particular sampling date was analyzed for selected chemical and physical parameters.

8.6.2.5 Discussion and Results

During 1981, 146 taxa were identified in samples collected at Stewart, Middle, and Hunter Stations, in Piceance Creek. The taxa consisted of 123 diatoms (Bacillariophyta), 12 green algae (Chlorophyta), 2 yellow-brown algae (Chrysophyta), 6 blue-green algae (Cyanophyta), 2 euglenoids (Euglenophyta), and 1 red alga (Rhodophyta). Periphyton data listings for each sample period, enumeration data, biomass data, density, relative abundance, and diversity indices are given for each station during each sample period, biomass analysis results, a listing of all periphyton taxa observed at each station over all sample periods during 1981, and taxa listings for each sample date by

station were presented in Tract C-b Development Monitoring Report #7, Volume 3, Section 2.5.2 (Aquatic Studies).

Variations in periphyton densities were present during the 1981 study period. The highest densities for Stewart Station ocurred in May and October while highest densities for Middle and Hunter stations occurred in October (Table 8.6.2-1). Increased density at all stations in October 1981 was probably due to the increased number of diatoms which typically dominate the winter flora of temperate streams (Hynes (1970).

Throughout the 1981 study period, diatoms numerically dominated the periphyton communities accounting for 78 to 100% of the total relative abundance of all algae. Seasonal variation in algal relative abundance was apparent. While Achnanthes and Cocconeis species were dominant in the spring and fall, Nitzschia and Synedra species increased in numerical importance during the summer.

Based on comparisons of 1981 sampling data to periphyton analyses of previous years (Tables 8.6.2-2, 8.6.2-3, and 8.6.2-4), annual variations also seem to be occurring in Piceance Creek. In 1979, Achnanthes species dominated the periphyton in all samples and seasonal variations in dominance were noted for Cocconeis placentula, Fragilaria vaucheriae, Nitzschia species, and Gomphonema species. Seasonal variations in 1978 were similar to trends reported in 1980 and 1981. However, the dominance of Navicula viridula in the algal community during the spring of 1981 was simiair to its occurrence in the spring of 1977.

Only qualitative periphyton data were obtained in 1974-1976 (C-b Annual Report 1977). As a result, no information is available for comparison of relative abundance and dominance. Since Middle Station was initiated into the monitoring program in 1979, comparison of the three stations can only be made subsequent to 1979. The Stewart Station site was moved to its present location after the 1977 sampling season. Hence, quantitative comparisons can be made for this station from 1978 to 1981, while quantitative records for Hunter Station are available from 1977 to 1981.

The dominant members of the periphyton community at Stewart Station in 1981 are presented in Table 8.6.2-2 along with quantitative results from previous years. The occurrence of Draparnaldia glomerata as a dominant species in the Summer of 1981 provides some evidence that clear and cool stream conditions prevailed at that time, since this green algae is usually found only in clear, cool running waters (Smith (1950).

The dominant numbers of Gomphonema angustatum in October 1981 can be attributed to seasonal variation, since this species usually has its maximum development in the fall and winter (Lowe (1974). The 1981 fall diatom community at Stewart Station was similar to the 1980 fall flora. The diatom assemblages in the Fall of 1978 and 1979 were quite different. Such dominant species as Achnanthes lanceolata, A. minutissima, and Cocconeis placentula may indicate that the artificial substrates were not incubated long enough in Fall 1978 and 1979 or that severe scouring occurred during those periods. Cholnoky (1968) states that these species are typically the first algae to colonize glass slides or disturbed areas.

TABLE 8.6.2-1

MEAN DENSITIES (units/mm^2) OF PERIPHYTON SAMPLES COLLECTED FROM PICEANCE CREEK, MAY THROUGH OCTOBER 1981, TRACT C-b

Sample Date	Stewart Station	Middle Station	Hunter Station
May 28	14252	7033	13063
June 30	4619	5220	7551
July 30	3294	12361	18489
August 31	6789	11172	14942
September 30	4700	13989	15044
October 29	13143	15219	29458

TABLE 8.6.2-2

DOMINANT PERIPHYTON SPECIES (>5% mean relative abundance) OCCURRING AT STEWART STATION, FROM 1978 THROUGH 1981
(values rounded to the nearest percent)

SPECIES	MEAN DENSITY (units/mm^2) 1978	1979	1980	1981
MAY				
Achnanthes minutissima	+1/	11	2/	+
Navicula cryptocephala var. veneta	13	- 3/		+
N. secreta var. apiculata	12	19		7
N. tripunctata var. schizomoides	6	-		-
N. viridula var. avenacea	+	42		60
N. spp.	8	+		-
Nitzshic dissipata	-	-		6
N. palea	7	-		+
N. spp.	27	10		-
Surirella angustata	+	+		-
S. ovata	5	+		+
unidentified pennate diatoms	5	-		-
LATE JUNE - EARLY JULY				
Achnanthes minutissima	7	13	+	10
Fragilaria vaucheriae	-	6	+	+
Gomphonema olivaceum	+	6	+	+
G. parvulum	+	9	-	-
Navicula cryptocephala var. veneta	+	-	+	5
N. secreta var. apiculata	9	-	7	-
N. viridula	-	-	44	28
N. v. var. avenacea	+	28	-	-
Nitzschia acicularis	25	+	+	-
N. fonticola	-	-	7	-
N. frustulum	-	-	-	16
N. palea	9	-	7	+
N. spp.	42	19	-	-
Surirella ovata	+	+	9	+
Synedra ulna var. oxyrhynchus	-	+	-	6

Table 8.6.2-2 (continued)

SPECIES	MEAN DENSITY (units/mm^2) 1978	1979	1980	1981
LATE JULY - EARLY AUGUST				
Achnanthes lanceolata	9	14	+	-
A. l. var. dubia	41	+	+	+
A. minutissima	35	29	6	16
Cocconeis placentula	-	-	+	13
C. p. var. euglypta	+	34	-	-
Navicula secreta var. apiculata	+	-	13	-
N. viridula	-	-	25	+
N. v. var. avenacea	+	10	-	-
Nitzshia dissipata	-	-	20	6
N. frustulum	-	-	9	15
Rhoicosphenia curvata	+	-	+	9
palmella stage of Chaetophoraceae	-	-	-	11
Phormididium sp.	+	-	-	8
LATE AUGUST - EARLY SEPTEMBER				
Achnanthes lanceolata	+	14	+	-
A. l. var. dubia	32	-	-	+
A. minutissima	13	57	42	+
Cocconeis pediculus	11	-	-	+
C. placentula var. euglypta	9	22	-	-
Gomphonema angustatum	-	-	+	6
Navicula secreta var apiculata	7	-	+	6
Nitzschia dissipata	-	-	28	10
N. frustulum	-	-	5	16
N. holsatica	-	-	-	6
N. palea	-	-	+	7
Draparnaldia sp.	-	-	-	13
LATE SEPTEMBER				
Achnanthes lanceolata var. dubia	+	4/	12	14
A. minutissima	84		25	19
Cocconeis pediculus	6		+	+
C. placentula	-		42	39
Nitzschia dissipata	-		10	+
palmella stage of Chaetophoraceae	-		+	15

Table 8.6.2-2 (continued)

SPECIES	MEAN DENSITY (units/mm²) 1978	1979	1980	1981
OCTOBER				
Achnanthes lanceolata	+	7	-	-
A. minutissima	75	79	47	+
Cocconeis pediculus	7	-	+	+
Gomphonema angustatum	-	-	-	7
G. olivaceum	+	+	8	+
Navicula secreta var. apiculata	+	+	6	+
N. viridula var. avenacea	+	+	11	13
Nitzschia dissipata	+	-	9	12
N. frustulum	-	-	+	7
N. palea	-	-	+	7
Rhoicosphena curvata	+	+	+	7

1/ + = present at <5% mean relative abundance

2/ Periphyton not sampled in May 1980

3/ - = absent

4/ Periphyton not sampled in September 1979

TABLE 8.6.2-3

DOMINANT PERIPHYTON SPECIES (>5% mean relative abundance) OCCURRING AT MIDDLE STATION, FROM 1979 THROUGH 1981 (values rounded to the nearest percent)

SPECIES	MEAN DENSITY (units/mm²) 1979	1980	1981
MAY			
Achnanthes lanceolata	1/	1/	43
A. minutissima			19
Cocconeis placentula			5
Chaetophoraceae sp.			19
LATE JUNE - EARLY JULY			
Achnanthes lanceolata	30	+2/	+
A. minutissima	9	+	-
Navicula secreta var. apiculata	-	8	-
N. viridula	-	+	24
N. v. var. avenacea	23	-	-
Nitzschia acicularis	+	11	-
N. dissipata	-	+	14
N. frustulum	-	+	28
N. holsatica	-	26	+
N. palea	-	10	+
N. spp.	14	-	-
palmella stage of Chaetophoraceae	-	5	-
LATE JULY - EARLY AUGUST			
Achnanthes lanceolata	6	+	+
A. minutissima	45	+	33
Gomphonema angustatum	-	+	5
G. parvulum	15	-	-
Navicula secreta var. apiculata	-	19	-
N. viridula	-	30	+
Nitzschia frustulum	-	+	21
N. holsatica	-	9	-
N. palea	-	14	+
N. spp.	8	-	-
Rhoicosphena curvata	+	+	11
Cladophora sp.	11	-	+

Table 8.6.2-3 (continued)

SPECIES	MEAN DENSITY (units/mm^2) 1979	1980	1981
LATE AUGUST - EARLY SEPTEMBER			
Achnanthes lanceolata	29	8	-
A. minutissima	42	48	5
Cocconeis placentula	-	20	+
C. p. var. euglypta	21	-	-
Diatoma tenue var. elongatum	-	-	11
Fragilaria crotonensis	+	-	21
Synedra fasciculata	-	-	13
S. ulna var. oxyrhynchus	-	-	5
palmella stage of Chaetophoraceae	-	7	+
LATE SEPTEMBER			
Achnanthes lanceolata var. dubia	4/	11	+
A. mintussima		59	39
Cocconeis placentula		12	14
Gomphonema angustatum		-	9
palmella stage of Chaetophoraceae		5	10
OCTOBER			
Achnanthes lanceolata	18	+	-
A. mintussima	44	15	6
Cocconeis placentula var. euglypta	5	-	-
C. p. var. lineata	7	-	-
Cymbella minuta var. silesiaca	-	5	+
Cymbella minuta var. veneta	-	5	14
N. secreta var. apiculata	7	9	+
N. viridula var. avenacea	5	31	16
Nitzschia spp.	5	-	+
Rhoicosphenia curvata	+	+	5
palmella stage of Chaetophoraceae	-	11	-

1/ Periphyton not sampled in May 1979 and 1980

2/ + = present at <5% mean relative abundance

3/ - = absent

4/ Periphyton not sampled in late September 1979

TABLE 8.6.2-4

DOMINANT PERIPHYTON SPECIES (>5% mean relative abundance) OCCURRING AT HUNTER STATION, FROM 1977 THROUGH 1981
(values rounded to the nearest percent)

SPECIES	MEAN DENSITY (units/mm²)				
	1977	1978	1979	1980	1981
MAY					
Achnanthes lanceolata var. dubia	+1/	+	+	2/	10
A. minutissima	+	6	8		51
Navicula secreta var. apiculata	+	11	9		+
N. tripunctata var. schizonemoides	-3/	15	-		-
N. viridula var. avenacea	65	+	57		13
N. spp.	+	5	+		-
Nitzschia palea	5	6	-		6
N. spp.	+	26	16		-
unidentified pennate diatoms	+	7	-		-
Stigeoclonium tenue	-	+	-		6
LATE JUNE - EARLY JULY					
Achnanthes lanceolata var. dubia	4/	8	6	+	+
A. minutissima		8	+	+	+
Gomphonema parvulum		+	23	-	-
Navicula secreta var. apiculata		+	-	5	-
N. viridula		-	-	58	13
N. v. var. avenacea		11	48	-	-
Nitzschia acicularis		31	-	+	-
N. frustulum		-	-	-	5
N. holsatica		-	-	13	-
N. linearis		-	-	+	9
N. palea		11	-	11	5
N. spp.		17	15	-	-
Surirella ovalis		+	-		13
S. ovata		+	+	5	+
Synedra ulna		-	+	-	7
Thalassiosira fluvialis		-	-	-	26

Table 8.6.2-4 (continued)

SPECIES	1977	1978	1979	1980	1981
	MEAN DENSITY (units/mm^2)				
LATE JULY - EARLY AUGUST					
Achnanthes lanceolata	5/	6	7	+	-
A. l. var. dubia		26	+	-	+
A. minutissima		38	41	+	61
Gomphonema parvulum		+	13	+	-
Navicula cryptocrphala		-	7	+	-
N. secreta var. apiculata		+	-	9	-
N. viridula		-	-	67	+
N. v. var. avenacea		+	8	-	-
Nitzschia dissipata		-	-	5	6
N. frustulum		-	-	+	7
N. spp.		+	14	-	-
Rhoicosphenia curvata		+	+	+	5
Stigeoclonium sp.		9	-	-	-
LATE AUGUST - EARLY SEPTEMBER					
Achnanthes lanceolata	6/	+	12	+	-
A. l. var. dubia		23	-	+	+
A. minutissima		32	76	50	27
Cocconeis pediculus		12	-	+	-
C. placentula		-	-	5	+
C. p. var. euglypta		6	7	-	-
Cymbella minuta var. silesiaca		-	-	+	7
Gomphonema angustatum		-	-	+	13
Navicula viridula var. avenacea		+	+	-	9
Nitzschia dissipata		+	-	10	19
palmella stage of Chaetophoraceae		-	-	11	-
LATE SEPTEMBER					
Achnanthes lanceolata var. dubia	7/	8/	7/	31	+
A. minutissima				16	37
Cocconeis pediculus				10	-
C. placentula				30	+
Cymbella minuta var. silesiaca				+	10
Gomphonema angustatum				-	10
Nitzschia dissipata				+	6
N. frustulum				+	9
Stigeoclonium tenue				-	7

Table 8.6.2-4 (continued)

SPECIES	MEAN DENSITY (units/mm^2) 1977	1978	1979	1980	1981
OCTOBER					
Achnanthes lanceolata	-	-	49	+	+
A. l. var. *dubia*	+	9	-	+	6
A. minutissima	+	+	20	5	21
Cocconeis pediculus	+	6	-	+	-
C. placentula	15	+	-	+	6
C. p. var. *euglypta*	-	27	+	-	-
Gomphonema angustatum	-	-	-	-	8
G. olivaceum	+	+	+	+	8
Navicula cryptocephala var. *veneta*	-	+	-	+	6
N. secreta var. *apiculata*	23	10	10	+	+
N. viridula var. *avenacea*	22	28	10	72	+
Nitzschia frustulum	-	-	-	+	12
N. palea	+	-	-	-	5
N. spp.	12	-	-	-	-
palmella stage of Chaetophoraceae	-	-	-	5	+

1/ + = present at <5% mean relative abundance

2/ Periphyton not sampled in May 1980

3/ - = absent

4/ Periphyton not sampled in late June - early July 1977

5/ Periphyton not sampled in late July - early August 1977

6/ Periphyton not sampled in late August - early September 1977

7/ Periphyton not sampled in late September 1977 and 1979

8/ Sampler destroyed in 1978

The same situation occurred at Middle Station in the Fall of 1979 (Table 8.6.2-3). Again, the dominant numbers of Achnanthes lanceolata, A. minutissima, and Cocconeis placentula may indicate too short an incubation time for the artificial substrates or that severe scouring occurred prior to their collection.

The quantitative data for Hunter Station from 1977 to 1981 are summarized in Table 8.6.2-4 and indicates substantial annual and seasonal variability. Most of the algal taxa observed during the eight-year study of Piceance Creek are those with similar environmental requirements. These taxa are common in this region and characteristic of alkaline waters (pH >7) with high dissolved oxygen, relatively high inorganic material concentrations, and medium organic load where oxidation is proceeding (Cholnoky (1968); Lowe (1974). Most of the taxa recorded as abundant are considered to be cold water forms.

Differences in sampling techniques and levels of taxonomic expertise may have been responsible for some of the variation observed over the years. In addition, the glass slide incubation time may not have been long enough on some sampling dates. As a result, the flora collected on these dates may have been in the phase of accumulation rather than the more stable phase of reconstruction (Hutchinson (1975). The organisms which are flat and can attach themselves directly to the substrate are usually the first to colonize glass slides. Examples include Achnanthes lanceolata, A. minutissima, Cocconeis pediculus, and C. placentula. Stalk and tube-forming diatoms occur during the reconstruction phase; Cymbella species, Gomphonema species, and Navicula viridula are examples of these organisms. Also, annual differences may have been due to a combination of environmental factors such as light (turbidity), temperature, flow rate, nutrients, and pH. Any or all of these factors may vary on an annual basis regardless of man-made perturbations.

Analysis of variance was used to test for significant differences (p = 0.01 level) in total periphyton densities. Generally, all stations were significantly different than each other during the 1981 study period. However, the periphyton densities of Middle Station were not significantly different than the periphyton densities at Hunter Station during May, June, August, and September 1981. The periphyton densities at Hunter Station were significantly different than Stewart and Middle Stations in July and October 1981. Significant differences in periphyton densities in 1981 were found between May and June, June and September, June and October, as well as August and September. No significant differences in periphyton densities were found between 1980 and 1981 for Stewart and Middle Stations. However, the 1981 Hunter Station algal densities were significantly different than the 1980 values.

No seasonal trends were apparent in the 1981 ash-free dry weight biomass productivity (Table 8.6.2-5). In 1975, 1976, 1977, 1979, and 1980, biomass productivity was usually higher at Stewart Station than at Hunter Station, but was higher at the latter station in 1978 and 1981. In 1979, biomass productivity at Middle Station was generally higher than at Hunter Station, while Stewart and Middle Stations alternated positions throughout the year. In 1980, biomass productivity at Middle station tended to be higher than at the other two stations. However, the 1981 biomass at Middle

TABLE 8.6.2-5

MEAN PERIPHYTON BIOMASS (g/ash-free dry weight 37.5 cm^2) FROM PICEANCE CREEK, MAY THROUGH OCTOBER 1981, TRACT C-b

Sample Date	Stewart Station	Middle Station	Hunter Station
May 28	0.723	0.074	0.327
June 30	0.461	0.413	0.335
July 30	0.044	0.288	0.308
August 31	0.227	0.350	0.417
September 30	0.055	0.201	0.188
October 29	0.144	0.362	0.331

Station was generally higher than Stewart Station but lower than Hunter Station.

Statistical comparisons of 1981 periphyton biomass values among stations and months were accomplished using analysis of variance at the $p = 0.01$ level. Comparison of biomass values from all stations throughout the study period indicates no significant differences in productivity between stations. However, significant differences in periphyton biomass occurred between June and September as well as August and September 1981.

Statistical comparisons of total species among stations and months in 1981 and between 1980 and 1981 were accomplished using analysis of variance at the $p = 0.01$ level. No significant differences were found between stations or months in 1981. The total number of species observed in 1981 at Stewart, Middle, and Hunter Stations was not significantly different than the 1980 total.

Species diversity indices for all 1981 samples are summarized in Table 8.6.2-6. Diversities at Stewart, Middle, and Hunter Stations were highest during fall. In 1980, diversities at Stewart and Middle Stations were highest during summer but were highest in early fall at Hunter Station. In 1979, highest values occurred during summer months, while the lowest occurred in fall. Diversity values in 1978 decreased steadily at Stewart and Hunter Stations between May and July but increased in August. Lowest values for both stations occurred in fall. The low density values recorded in 1978, 1979, 1980, and 1981 occurred mainly when Achnanthes species and Cocconeis species dominated the periphyton. These genera are early colonizers of glass slides. Species diversity values are usually low during the earliest stage of colonization (Hutchinson (1975).

8.6.2.6 Conclusions

Analysis of periphyton data does not indicate any effect which could solely be attributed to project operations. Although statistical analysis does show significant differences between stations, no definite trend relating these differences to the control station versus the two test stations was established. Comparisons to previous studies, including the baseline conditions, appear to rule out Tract C-b discharge as being a major reason for this difference. The changes observed seem to be attributable primarily to agricultural impacts and natural variations.

TABLE 8.6.2-6

SHANNON-WEINER DIVERSITY (H'), EVENNESS (E), AND TOTAL NUMBER OF TAXA (N) IN PERIPHYTON SAMPLES COLLECTED FROM PICEANCE CREEK, MAY THROUGH OCTOBER 1981, TRACT C-b

	Stewart Station			Middle Station			Hunter Station		
Sample Date	H'	E	N	H'	E	N	H'	E	N
May 28	1.83	0.51	36	1.76	0.55	25	1.82	0.56	26
June 30	2.64	0.69	45	2.37	0.61	50	2.49	0.69	37
July 30	2.69	0.71	45	2.40	0.64	43	1.66	0.50	28
August 31	3.07	0.74	63	3.00	0.76	52	2.42	0.64	45
September 30	1.89	0.56	29	2.23	0.62	37	2.33	0.64	37
October 29	3.18	0.76	64	3.23	0.76	70	2.82	0.73	48

8.7 Terrestrial Studies

The terrestrial studies portion of the Environmental Baseline Program was designed to describe the predevelopment biological environment within the C-b study area and to provide baseline data to be used in monitoring changes in the biota as a result of oil shale development. Baseline parameters were selected for their usefulness in describing the existing environment on Tract C-b. Development monitoring parameters were judged to be useful because of their measurability or relatively low natural variability, and/or sensitivity to expected environmental perturbations.

8.7.1 Vegetation Community Structure and Composition

8.7.1.1 Scope

The vegetation community structure and composition studies evaluate major changes in the make-up of the major plant communities on the Tract. Other vegetation monitoring programs provide a better means for statistically evaluating changes. The structural and compositional studies are better used for evaluating general vegetative trends. These studies are centered on the six intensive study sites established during 1974 and sampled on a three-year rotational basis. Chained pinyon-juniper rangeland Plots 1 and 2 (BJ01 and BJ02) were sampled in 1978 and again in 1981, pinyon-juniper woodland Plots 5 and 6 (BJ05 and BJ06) were sampled in 1979, and sagebrush Plots 3 and 4 (BJ03 and BJ04) were sampled in 1980.

8.7.1.2 Objectives

The objective of the community structure and composition studies is to obtain long-term data from permanently located sampling quadrats to evaluate differences in numerous species with respect to long-term trends. The productivity studies, discussed later, focus on monitoring a process; the structure and composition studies focus on performances of species within the major vegetation types.

8.7.1.3 Experimental Design

The community structure and composition studies are conducted at the six intensive study plots. Two are located in the pinyon-juniper woodland type, two in the chained rangeland type and one each in the bottomland sagebrush and upland sagebrush types. At each location a grid of 25 1.0 m^2 quadrats has been established in a permanently fenced and in an adjoining open area (a grid in each for a total of 50 quadrats for each site). Observations on the herb and ground-layer components are made in the 1.0 m^2 quadrats.

Shrubs are sampled along line-strip transects. The center posts marking the herb quadrats serve as end points of the transects, thus producing a total of 20 line-strips per grid. The herb quadrats are established on 10-meter centers. The line-strips are 10 meters long and 4 meters wide. Shrub cover estimates are obtained using a 10-meter line intercept located in the center of the line-strip. Density estimates are obtained by counting the number of individuals of each species within the

line-strip. Individuals are recorded on the basis of height classes so that it is possible to obtain measures of population structure.

In the woodland plots canopy cover for tree species is recorded along the same 10-meter line intercept used for estimating shrub cover. All of the trees within the area defined by the herb quadrat grid (40 meters by 40 meters) have been tagged and numbered. Changes in tree diameter are evaluated by repeated measurement of these trees.

In addition to the six intensive study sites, a seventh site was added in 1980. This plot is located in the chained rangeland type within the area irrigated. This plot was sampled in 1980 and will be sampled in conjunction with the other chained rangeland sites as long as the irrigation program continues.

The parameters being monitored in this study include: cover and frequency for herbaceous species; cover, frequency and density for shrubs; and diameter and canopy cover for tree species.

8.7.1.4 Method of Analysis

Data from the community structure and composition studies are mainly being evaluated through use of trend analysis. Total vegetation composition changes are being evaluated by examining trends in similarity indices.

8.7.1.5 Discussion and Results

8.7.1.5.1 Chained Rangeland Study Plots

The 1981 sampling of the chained rangeland study plots constitutes the fourth time that they have been sampled. The four sampling dates span the years 1975-1981. During this time no major changes have been noted in the vegetation. The changes which have been observed tend to relate to small fluctuations in community composition, and to minor differences related to data collection. To date, the development of the Tract has been limited to the construction of surface facilities and development of the mine shafts. These activities have impacted the vegetation in only those areas directly involved with construction. It is safe to say that since 1974 the vegetation studies program has been monitoring natural fluctuations in the vegetation on Tract C-b. No effects of development have been noted except for those mentioned above.

Monitoring vegetation changes in the chained rangeland type poses a problem not encountered in the other vegetation types on the Tract. Since the original pinyon-juniper woodland was destroyed by chaining, it can be expected that over the years the chained areas will eventually return to a woodland type. This successional process will likely take at least 150 years. It has been approximately 15 years since the site was chained. With only 10 percent of the regeneration time span completed, it is not surprising that the chained areas are very similar in appearance to what they were immediately after chaining. After 15 years some recovery can be seen, especially with regard to small saplings of pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) which were not destroyed by the

chaining process. These saplings have grown and now form a conspicuous component of the chained areas.

Herb layer species composition at Plot 1-0 (BJ01) has not changed much over the past seven growing seasons (Table A8.7.1-1). The major species are crested wheatgrass (Agropyron desertorum) (3.2 percent cover; 40 percent frequency), Indian ricegrass (Oryzopsis hymenoides) (1.9 percent cover; 64 percent frequency), and small individuals of antelope bitterbrush (Purshia tridentata) (1.0 percent cover; 32 percent frequency). Other important species include needle-and-thread grass (Stipa comata), cheatgrass (Bromus tectorum). and pussytoes (Antennaria rosea). Total herb cover was only 8.4 percent, and total woody cover in the herb layer was only 1.4 percent. Total species density had a mean value of 5.16 species per square meter.

The total species composition has not changed much at Plot 1-0 since 1975 (Table A8.7.1-2). The major fluctuations occur with annual species and with species that are difficult to distinguish in vegetative condition. For example, western wheatgrass (Agropyron smithii) decreased in frequency from 52 percent in 1978 to 12 percent in 1981. During this same period slender wheatgrass (Agropyron trachycaulum) increased from 0 to 16 percent. These changes most likely relate to errors in identification rather than to any changes in community structure. Frequency for tansy mustard (Descurainia pinnata) has decreased from 40 percent in 1975 to only 4 percent in 1981. This change represents a real difference, since tansy mustard is easy to identify; and being an annual species, it is much more likely to be present in one year and absent in the next. Over all, there is no clear trend suggesting any major changes in the species composition at Plot 1-0. The frequency values for antelope bitterbrush increased from zero percent in 1978 to 32 percent in 1981. This increase is likely related to the inclusion of small sprouts of bitterbrush in the sampling data. These sprouts may not have been included in the past.

Since 1975, mean cover has shown a decreasing trend at Plot 1-0 (Table A8.7.1-3). Mean cover was 15.0 percent in 1975, 17.5 percent in 1976, 12.3 percent in 1978, and 8.4 percent in 1981. The decrease in cover has been coupled with an increase in litter cover which has increased from 63.0 percent in 1975 to 75.8 percent in 1981. It is suspected that these differences are related to changes in estimating technique rather than actually representing actual changes in plant cover. Much of the cover at Plot 1-0 is attributable to perennial grasses, for which cover estimation is difficult. This is especially true for bunchgrasses like Indian ricegrass. It appears that over the years, the tendency has been to reduce the estimate for plant cover and increase the estimate for litter. Species density has decreased slightly since 1978 changing from 6.6 to 5.2 species per square meter (Table A8.7.1-3).

The vegetation at Plot 1-F (BJ11) is very similar to that at Plot 1-0. The major species include Indian ricegrass (4.5 percent cover; 72 percent frequency), thickspike wheatgrass (Agropyron dasystachyum) (3.3 percent cover; 48 percent frequency), and muttongrass (Poa fendleriana). Other common species include cheatgrass, prairie junegrass (Koeleria gracilis) and small individuals of big sagebrush (Artemisia tridentata) (Table A8.7.1-4). Total herb cover was 12.9 percent, and cover by

woody species in the herb layer was only 0.3 percent. Species density had a mean value of 5.6 species per square meter.

No major changes have occurred in the species composition at Plot 1-F over the past seven years (Table A8.7.1-5).

The kinds of differences mentioned for Plot 1-0 are also true for Plot 1-F. The perennial forbs tend to have the most consistent freqency values from year to year. This is most likely related to their relative ease of identification, and to the fact that they are usually quite obvious in the sample quadrats.

At Plot 1-F mean cover has also shown a downward trend, and litter cover has shown an upward trend (Table A8.7.1-3). It is likely that the plant cover values will stabilize between 10 and 15 percent, unless several consecutive years of above normal precipitation occur.

The vegetation at Plot 2-0 (BJ02) is similar to the Plot 1 sites in terms of species composition; however, the vegetation is somewhat more sparse. The major species are cheatgrass (1.9 percent cover; 96 percent frequency), crested wheatgrass (1.6 percent cover; 44 percent frequency), and squirreltail grass (Sitanion longifolium) (0.2 percent cover; 36 percent frequency) (Table A8.7.1-6). Small individuals of big sagebrush had a mean cover of only 0.2 percent, but had a frequency of 44 percent. As with the other chained rangeland plots, the most obvious features of the area are the fallen trees and branches. Bare soil had a mean cover of 16 percent, and litter covered approximately 82 percent of the ground. Species density had a mean value of 4.64 species per square meter.

Over the past seven years there have been no major changes in the species composition at Plot 2-0 (Table A8.7.1-7). The same problems related to species identification have also been a problem at Plot 2-0. While these problems tend to obscure some of the trends, they do not consititute a serious problem for evaluation of impacts. At Plot 2-0 the major fluctuations in frequency have been with annual forbs. Total herb cover has declined at Plot 2-0 from 21.0 in 1975 to 6.6 in 1981. This decline parallels the declines noted in other vegetation types and sampling sites and is most likely related to changes in the evaluation of plant cover. Litter has increased from 69 percent in 1975 to 82 percent in 1981. Total species density has declined from 5.8 to 4.6 species per square meter from 1975 to 1981 (Table A8.7.1-8).

The species composition at Plot 2-F (BJ12) is very similar to that at Plot 2-0. The major species are crested wheatgrass (4.2 percent cover; 48 percent frequency), thickspike wheatgrass (0.8 percent cover; 16 percent frequency), and cheatgrass (0.3 percent cover; 60 percent frequency) (Table A8.7.1-9). These three species account for approximately 71 percent of the cover at Plot 2-F. The most common woody species is big sagebrush which occurred at a frequency of 24 percent. Total herb cover was 7.0 percent, and litter cover was 80 percent. Species density was 3.96 species per square meter.

As with the other chained rangeland sites, the most common fluctuations in frequency occur with the annual forb

species (Table A8.7.1-10). Over the past seven years annual species like knotweed (Polygonum sawatchense) have had frequency values ranging from 32 to zero percent. Gaywings (Gayophytum ramosissimum) has ranged from 44 to 20 percent frequency. While these changes are of interest, annuals consititute only a minor component of the vegetation. Total cover has decreased from 23 percent in 1975 to 7 percent in 1981, and litter has increased from 64 percent to 80 percent. Total species density has declined from 5.4 species per square meter to 4.0 species per square meter (Table A8.7.1-8).

In the chained rangeland type, shrubs are the dominant life form, and contain most of the above ground biomass. Since 1974 several interesting trends can be seen in the shrub data (Tables A8.7.1-11 - Table A8.7.1-16). At all four of the chained rangeland sites mean shrub cover has shown an increasing trend. This increase is likely occurring in response to the past chaining. It is possible that the shrubs will continue to increase until the existing sapling populations of pinyon pine and Utah juniper begin to out-compete the various shrub species. Most of the increase in total shrub cover is attributable to big sagebrush and rubber rabbitbrush (Chrysothamnus nauseosus). The chaining was successful in increasing shrub cover and density; however, most of the increases were in populations of low wildlife utilization species. Density has also shown a general increasing trend, especially with regard to big sagebrush. The more palatable browse species like antelope bitterbrush, mountain mahogany (Cercocarpus montanus), and serviceberry (Amelanchier spp.) tend to not fluctuate as much relative to both cover and density. Collectively, big sagebrush accounts for most of the cover and density in the chained rangelands.

Overall trends in chained rangeland composition are being monitored using a similarity index. By the use of this index it is possible to see how the communities have changed over time. Similarity was calculated using the formula:

$$S.I. = \frac{2W}{a + b} \times 100$$

where

S.I. = Similarity Index
W = Sum of the amount of the comparison parameter shared by the sites being compared
a = Sum of the amount of the comparison parameter at one sampling location
b = Sum of the comparison parameter at the other sampling location

For the purposes of evaluating changes over time, the parameter being used is frequency of species in the herb layer. Several factors could be responsible for any observed changes in plot to plot similarity. The effect of long term fencing would be manifested by a decrease in similarity between the fenced and open plots at either of the two chained rangeland sites. Impacts related to development of the site might occur at one of the sites and not the other. This would appear in the data as a decrease in similarity between the two sites. In general, trends in decreasing similarity would suggest that the species composition is changing. The similarity index trend data suggest that no important changes in similarity

have occurred over the past seven years (Figure 8.7.1-1). Plots 2-0 and 2-F underwent a change in similarity between 1976 and 1978 but have not changed much between 1978 and 1981. Plots 1-0 and 2-0 have shown a slight increase in similarity. All of the changes seem to represent trends which can be accounted for by natural variability, and do not seem to be the result of site development.

8.7.1.5.2 Irrigation Study Plot - Chained Rangeland

The study plot established in the irrigated portions of the chained rangeland was re-sampled in 1981 (Table A8.7.1-17). Western wheatgrass, slender wheatgrass, cheatgrass, and Indian ricegrass all occur as major species. The total cover for the vegetation was approximately 15 percent, which is approximately twice that measured in the non-irrigated chained rangeland sites. Species density was also higher with a mean value of 8.96 species per square meter. Few differences can be seen in the frequency values obtained in 1980 and 1981 (Table A8.7.1-18). Differences related to problems in identification, especially with the wheatgrasses. Total plant cover increased from 10 percent in 1980 to 14.4 percent in 1981 (Table A8.7.1-19). This increase may well be related to the irrigation, since at the other chained rangeland sites cover has shown a decreasing trend. Species density increased slightly from 8.6 to 9.0 species per square meter.

Total shrub cover at the irrigation study plot was 14.1 percent which is comparable to that measured at the other chained rangeland study plots. While the total cover is comparable, density is somewhat less (Table A8.7.1-20). The major shrub species is big sagebrush.

8.7.1.6 Conclusions

There have been no major changes in the herb layer species composition over the last seven years. There has been a trend showing a decrease in total plant cover. This may be related to changes in cover estimation or, it may be related to the successional dynamics of the chained rangelands. Shrub species composition has not changed; however, total shrub cover and density have increased. None of the noted changes in the vegetation appear to be related to the development of the site.

8.7.2 Herbaceous Productivity and Utilization

8.7.2.1 Scope

Productivity of vegetation is intrinsically important in the operation of ecosystems on Tract C-b. The amount of production and availability of food are both of consequence for animal species within the system. Any significant interruption in production may well be manifested in changes throughout the ecological system. In terms of monitoring, herbaceous production is a very convenient parameter to measure and is a reflection of the total production in any of the communities on the Tract. By monitoring the herbaceous production it is possible to evaluate yearly and site-to-site differences in productivity. The scope of the herbaceous productivity and utilization studies includes sampling on a Tract-wide basis

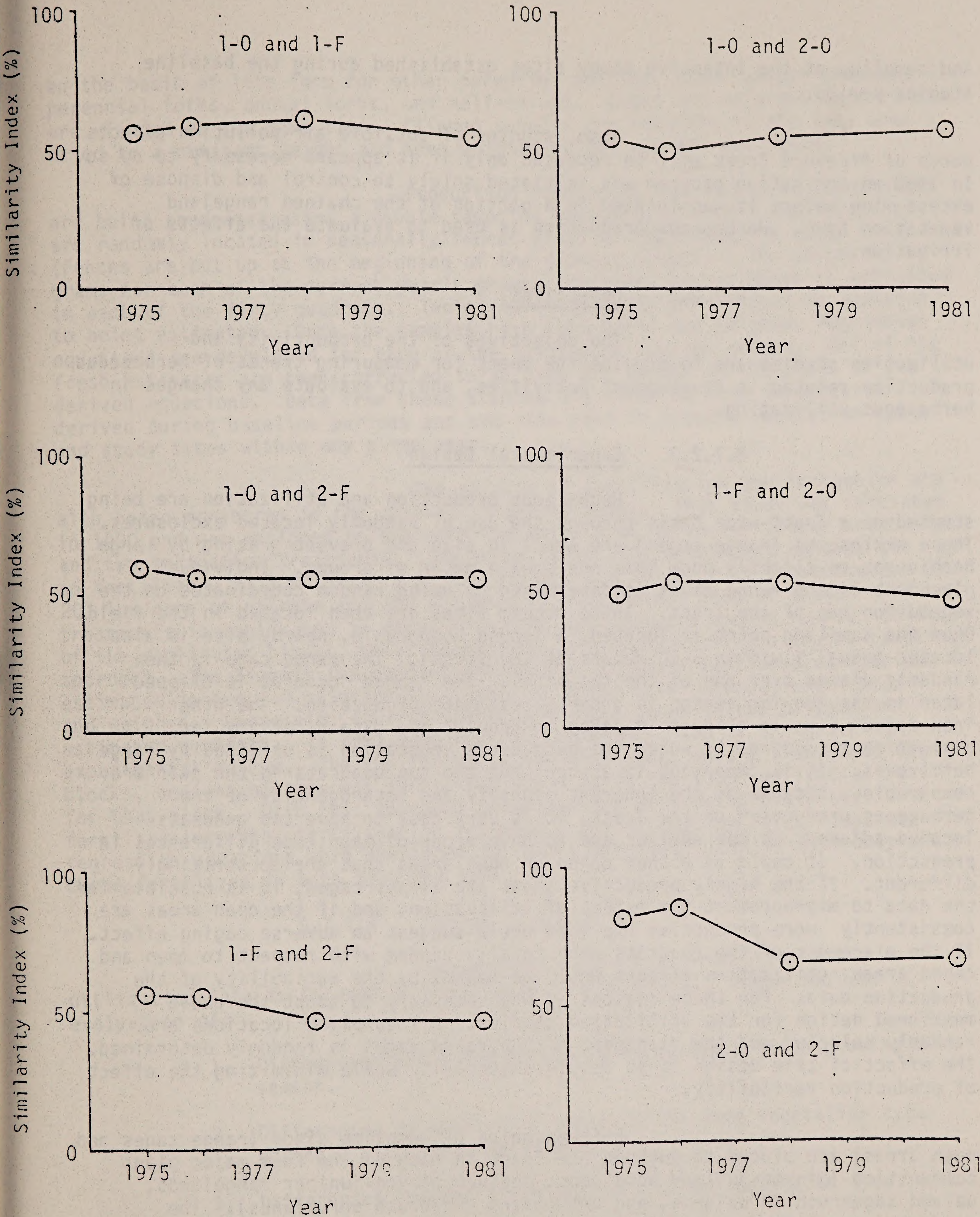


Figure 8.7.1 – 1. Trends in similarity index (based on herb layer species frequency)at Plots 1 and 2.

and sampling at the intensive study sites established during the baseline studies period.

Also, studies of possible air pollution effects north of Piceance Creek will be repeated only if it appears necessary to do so. In 1980 an irrigation program was initiated solely to control and dispose of excess mine water; it was located in a portion of the chained rangeland vegetation type. Herbaceous production is used to evaluate the effects of irrigation.

8.7.2.2 Objectives

The objectives of the productivity and utilization studies are to provide the means for measuring trends of herbaceous production related to development activities, and to evaluate any changes in herbaceous utilization.

8.7.2.3 Experimental Design

Herbaceous production and utilization are being studied on a Tract-wide basis through the use of randomly located exclosures. These exclosures (range cages) are small in size and prevent grazing by large herbivores on slightly more than one square meter of ground. Individual placement of the range cages is determined by using random coordinates on the vegetation map of the Tract. These random sites are then located in the field. Once the sampling point is located, a second comparable, nearby site is also located (usually within 5-10 meters of the first). The range cage is then randomly placed over one of the two sites. The "caged" quadrat is clipped later in the growing season in order to estimate production. The other "non-caged" site is clipped in order to provide the data necessary for evaluating the degree to which the herbaceous vegetation is utilized by large herbivores. It is important to assure that the two quadrats in the pair are comparable. Because of the inherent sparsity and heterogeneity of the herbaceous production on the Tract, it is very easy to have two quadrats located adjacent to one another and to have order-of-magnitude differences in production. It could be either caged or open areas that are so strikingly different. If the highly productive areas are always caged, it is possible for the data to misrepresent the extent of utilization, and if the open areas are consistently more productive the data would suggest an adverse caging effect. If the placement of the quadrats were totally random with respect to open and caged areas, utilization effects would be masked by the variability of the production data. For these reasons it was necessary to adopt the above mentioned design for the utilization studies. All sampling locations are randomly selected and the placement of the range cages is randomly determined. The effect of this design is to retain objectivity while minimizing the effect of production variability.

Fifteen pairs of sampling sites (range cages and open areas) are placed throughout the Tract in each of the four major plant communities (pinyon-juniper woodlands, chained pinyon-juniper rangelands, upland sagebrush shrublands, and bottomland sagebrush shrublands). The quadrats are clipped at peak season (approximately mid-late July), and all of the current year's growth is removed. Clipped samples are fractionized on the basis of species for western wheatgrass, cheatgrass and Indian ricegrass, and

on the basis of life form for other perennial grasses, other annual grasses, perennial forbs, annual forbs, and half-shrubs. Caged and adjacent open areas are clipped at the same time. Clipped samples are returned to the lab, oven dried to a constant weight and then weighed to the nearest milligram.

Production studies at the intensive study sites are being conducted using a double sampling approach. Fifty 1.0 m^2 quadrats are randomly located in seasonally fenced plots at the intensive study sites. (Fences are put up at the beginning of the growing season). The weight in grams for each of the current year's growth fractions listed above is estimated in each of the fifty quadrats. Ten of these quadrats are clipped in addition to being estimated. Once the samples have been dried and weighed, regression equations are developed for each of the species or species groups. All of the fresh estimates are then corrected to an oven dry weight on the basis of the derived equations. Data from these studies are compared with information derived during baseline periods and are also used to compare vegetation types and study sites within any given year.

The effects of fertilization and irrigation are also being monitored in the chained rangeland types. This study was initiated in 1980 and was designed to evaluate the effects of three fertilizer treatments and two irrigation treatments. The three fertilizer treatments consist of: 1) no fertilizer, 2) 100 lbs/acre of nitrate and 100 lbs/acre of phosphate and 3) 200 lbs/acre of nitrate and 100 lbs/acre of phosphate. Each of these treatments is replicated in areas irrigated for 12 hours and 18 hours. In each of the replicated blocks, total production is evaluated using a double sampling approach. The biomass for each of the sample fractions mentioned earlier was estimated in ten 1.0 m^2 quadrats. Three of these were clipped, oven dried and weighed. Regression equations were developed based on the clipped and estimated quadrats. In 1981 some modifications were made in the basic experimental design. The two fertilization treatments were divided into two blocks, and one of them was fertilized again using the 1980 application rate for that block. With this approach three factors were being evaluated: fertilization rate, fertilization frequency, and irrigation rate. Separate regression equations were developed for the plots fertilized in 1980 only and those fertilized in both 1980 and 1981.

8.7.2.4 Method of Analysis

Analysis of herbaceous production and utilization data is focused on five areas of comparison. These include evaluation of:

1. Differences among vegetation types during a given growing season.

2. Differences between study sites of the same vegetation type during a given growing season.

3. Differences between years within a given vegetation type.

4. Differences between fenced and open areas within a vegetation type during a given growing season.

5. Differences in production related to the addition of fertilizer and irrigation.

Total production is used as the parameter for comparison. Evaluation of differences is accomplished using trend analysis and one-way analysis of variance (F-test) to test whether or not the observed differences in means are significant. Effects of fertilizer and irrigation are evaluated using a non-nested two-way analysis of variance.

8.7.2.5 Discussion and Results

8.7.2.5.1 Tract-Wide Range Cage Studies

The purpose for conducting the Tract-wide range cage studies is to provide more broadly based estimates of production in the major vegetation types than can be obtained from the intensive study sites. Data from these studies can be used in evaluating trends and can also be compared using statistical tests. Because of the high variability of the data, the statistical tests are not overly sensitive and differences in means need to be rather large in order to be judged significant. An attempt has been made to obtain sufficient samples to be able to detect a 20 percent difference in means with 80 percent confidence. This level of adequacy was reached in the upland sagebrush and chained rangeland communities but was not attained in the bottomland sagebrush and pinyon-juniper woodland communities. Low production and patchy distribution of individual plants tend to make the latter two communities more variable.

Oven dry weights for range cages and open areas in the pinyon-juniper woodlands are presented in Table A8.7.2-1. Mean total production in the pinyon-juniper woodlands was 7.8 g/m^2 (60 lbs/acre). Most of the production was attributable to western wheatgrass and other perennial grasses (Table A8.7.2-2). In the open areas, mean production was 6.0 g/m^2 (53 lbs/acre). Comparison of the production data from the cages and adjacent open areas suggests that utilization by large herbivores was approximately 24 percent. This value was the lowest measured in all of the vegetation types. Major species in the open areas were perennial grasses and Indian ricegrass. Perennial forbs accounted for about 1.5 g/m^2 of production.

Oven dry weights for range cages and adjacent open areas in the chained rangelands are presented in Table A8.7.2-3. During 1981 the mean total production in the chained rangeland type was 43.6 g/m^2 (388 lbs/acre). Major species in both the open and fenced areas were western wheatgrass and other perennial grasses (Table A8.7.2-4). In the open areas, mean production was 16.8 g/m (150 lbs/acre), suggesting that utilization was approximately 62 percent. This was the highest amount of utilization in any of the types. It is interesting to note that the 1981 utilization percentages are some of the highest that have been recorded since production/utilization studies were initiated in 1975. Observations on-Tract suggested that the cattle were grazing on the site for a longer period than usual. This extended grazing time is clearly apparent in the production/utilization data.

Dry weight data for each of the range cages and adjacent open areas in the upland sagebrush type are presented in Table A8.7.2-5. Mean production for the upland sagebrush type was 37.8 g/m^2 (337 lbs/acre). Major species in this type include perennial grasses, perennial forbs, and western wheatgrass (Table A8.7.2-6). Mean total production for the open areas was 25.0 g/m^2 (223 lbs/acre) with the same species occurring as dominants. Utilization by large herbivores was approximately 34 percent.

Oven dry weight data for each of the range cages and adjacent open areas in the bottomland sagebrush shrubland type are presented in Table A8.7.2-7. Mean total production for the range cages was 33.7 g/m^2 (300 lbs/acre), and 15.0 g/m^2 (133 lbs/acre) in the adjacent open areas (Table A8.7.2-8). Major species included perennial grasses, western wheatgrass and cheatgrass. Utilization by large herbivores was approximately 56 percent.

The production patterns in the major vegetation types were somewhat different during 1981. The chained rangeland type was the most productive followed by the upland sagebrush shrubland type, bottomland sagebrush shrubland type, and the pinyon-juniper woodland type. In past years the upland sagebrush shrubland type has been the most productive followed by the chained rangeland, bottomland sagebrush shrubland, and pinyon-juniper woodland types. This difference is not of great consequence since the production differences between the upland sagebrush shrubland and chained rangeland types have never been statistically significant.

8.7.2.5.2 Intensive Study Plots

Production data were collected at Plots 1, 2, 5 and 6 (BJ21, BJ22, BJ25, and BJ26) during 1981. Plots 1 and 2 are in the chained rangeland type, and Plots 5 and 6 are in the pinyon-juniper woodland type. Fresh weight estimates for each of the quadrats are presented in Tables A8.7.2-9 - A8.7.2-12, and oven dry weights for each of the ten clipped quadrats at each plot are presented in Tables A8.7.2-13 and A8.7.2-14. The regression equations used to convert the fresh weight estimates to oven dry weights are presented in Tables A8.7.2-15 - A8.7.2-18. In some cases the regression equations were based on limited pairs of observations and were not reliable predictors of oven dry weight. In cases such as these, regression equations from other study plots were used. For estimates of western wheatgrass and other perennial grasses for Plot 1, the regression equations from Plot 2 were used. For half shrubs at Plot 1, the equation for perennial forbs at Plot 1 was used. For perennial grasses, perennial forbs, and half shrubs at Plot 5, the equations from Plot 6 were used. For cheatgrass at Plot 6, the equation from Plot 5 was used.

As observed in earlier years, the chained rangeland intensive study plots tend to be less productive than the chained rangeland type as a whole. Mean total production was 23.7 g/m^2 (211 lbs/acre) at Plot 1 and 21.3 g/m^2 (190 lbs/acre) at Plot 2. In the chained rangeland cages total production was 43.6 g/m^2. The major species are the same with most of the production attributable to perennial grasses, western wheatgrass and Indian ricegrass (Table A8.7.2-19).

The production pattern in the pinyon-juniper woodland plots was different in 1981. In all previous years, production at Plot 6 was greater than that at Plot 5. During 1981 the production at Plot 5 was greater than that at Plot 6 (Table A8.7.2-20). Mean production at Plot 5 was 10.7 g/m^2 (95 lbs/acre) and was 8.8 g/m^2 (78 lbs/acre) at Plot 6. Major species include western wheatgrass, Indian ricegrass, and other perennial grasses. During 1981 both of the intensive study plots were comparable to the pinyon-juniper woodland type as a whole where the total production was 7.8 g/m^2.

8.7.2.5.3 Trends in Herbaceous Production 1975-1981

In general, total production on Tract C-b during 1981 was approximately the same as 1980 (Table 8.7.2-1). The only major difference was at the pinyon-juniper woodland Plot 6 where production dropped from 37.7 g/m^2 to 8.8 g/m^2. In examining the long term trends in the pinyon-juniper woodland type (Figure 8.7.2-1) it can be seen that production values oscillate widely at Plot 6. It is suspected that these differences relate to the plot locations rather than to yearly fluctuations in production. The research design calls for sampling two different plots in alternate years. It can be seen from the data that one of the plots is much more productive than the other. The plot sampled in 1977, 1979, and 1981 is much more like Plot 5 and the pinyon-juniper woodland type as a whole. The plot sampled in 1978 and 1980 is more like the upland sagebrush type in terms of species composition and production. Since utilization is limited in the pinyon-juniper woodland type, it may be an improvement in the long term production study to eliminate the more productive of the two plots and use only the one which is more comparable to the type as a whole. Effects of long term fencing could be reduced by constructing the fence in April, and removing it in August once the clipping is completed in July. This would allow for fall grazing of the area and utilization during the winter months.

Production trends for the chained rangeland type are shown in Figure 8.7.2-2. The same trend noted at Plot 6 can also be seen to a limited extent for Plots 1 and 2. The years 1977, 1979, and 1981 tend to be relatively low years, while 1978 and 1980 tend to be higher. The differences between years are much less extreme, thus making the pattern less apparent. This same kind of pattern could be related to yearly differences in precipitation; however, in this case the pattern appears to be too regular to be totally caused by precipitation. Additionally, the range cage data do not show the same pattern. Between 1978 and 1979 the range cages and intensive study plots showed the same pattern. In 1980 the two intensive study plots showed an increase in production while the range cages showed a decrease. The range cage data fluctuations most likely result from differences in precipitation (a measure of type variability), and the intensive plot data fluctuations are likely resulting at least in part from differences in yearly plot location (a measure of site variability).

Production trends for the upland and bottomland sagebrush types are shown in Figure 8.7.2-3. For the first time in seven years of sampling the two types had production values approximately the

Table 8.7.2 —1. Mean production (g/m^2) ± the standard error of the mean for the major vegetation types on Tract C-b for 1975-1980. No range cages were sampled prior to 1978. Sagebrush study plots have not been sampled since 1977. See also Figures 8.7.2-1 to 8.7.2-3.

Vegetation Types	1975	1976	1977	1978	1979	1980	1981
Pinyon-Juniper Woodlands							
Plot 5	25.0±6.2	10.6±1.9	6.2±0.5	19.2±2.3	8.4±0.8	12.0±0.9	10.7±1.4
Plot 6	34.2±7.6	23.4±4.0	6.4±0.5	50.3±3.3	10.7±1.0	37.7±2.9	8.8±0.7
Range Cages				21.4±6.7	10.3±2.0	10.4±1.7	7.8±1.3
Chained Pinyon-Juniper Rangelands							
Plot 1	49.3± 6.3	23.2±4.6	11.9±0.9	29.5± 2.5	20.7±1.3	30.6±2.3	23.7±2.2
Plot 2	57.8±18.6	24.4±5.6	12.5±1.2	24.4± 1.7	15.4±1.1	21.8±1.6	21.3±2.3
Range Cages				63.5±13.9	34.6±6.2	40.8±3.5	43.6±5.7
Upland Sagebrush Shrublands							
Plot 3	63.0±6.8	25.5±3.1	18.2±0.6	N.S.*	N.S.*	N.S.*	N.S.*
Range Cages				68.0±10.7	46.7±4.9	42.8±3.8	37.8±2.87
Bottomland Sagebrush Shrublands							
Plot 4	39.6±9.0	15.41±3.1	4.5±0.7	N.S.*	N.S.*	N.S.*	N.S.*
Range Cages				32.9± 6.1	28.4±5.1	27.0±6.8	33.7±9.8

*N.S. = Not Sampled

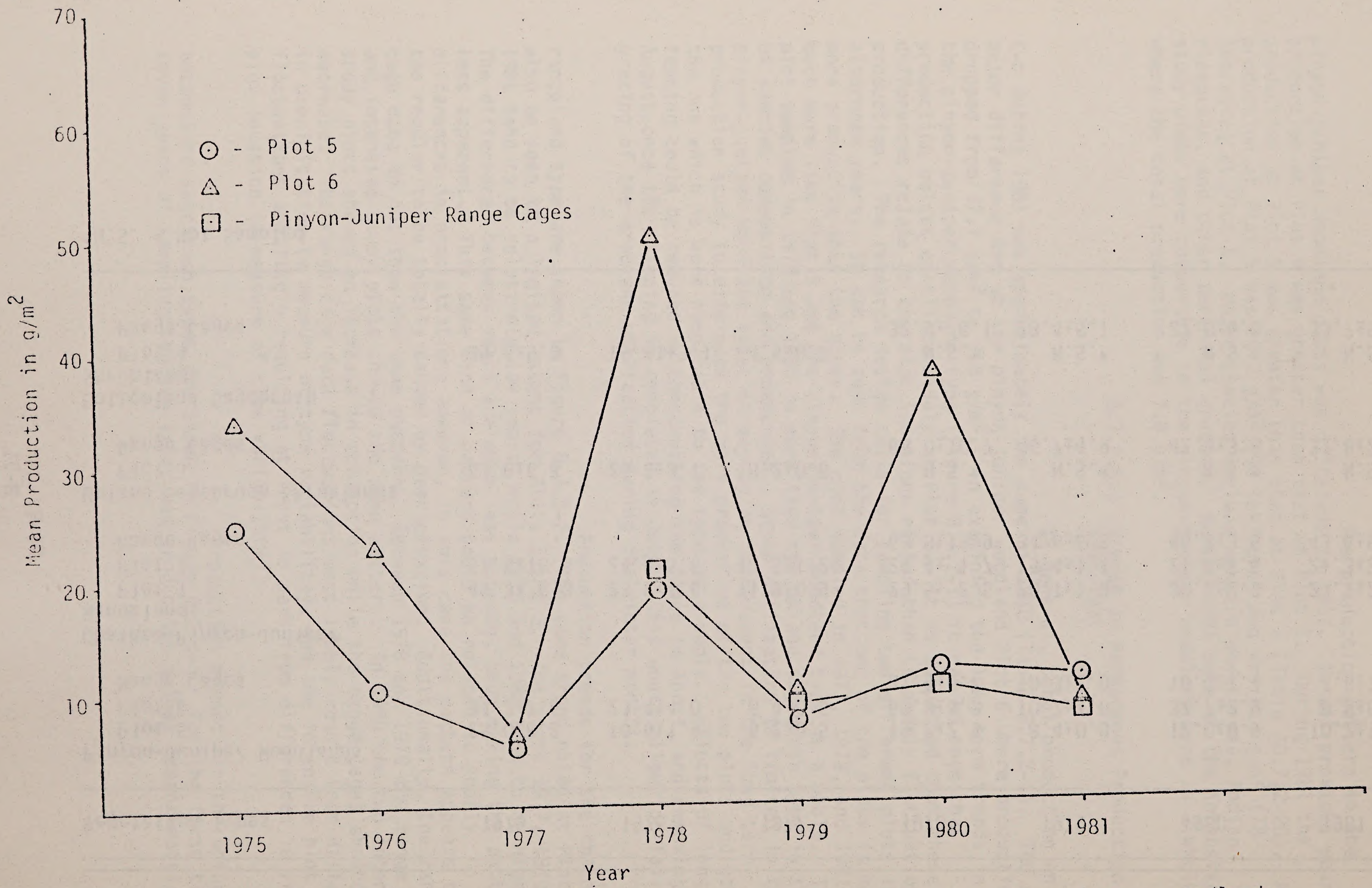


Figure 8.7.2 – 1. Trends in mean herb production between 1975 and 1981 for pinyon-juniper woodlands. See Table 8.7.2-1 for actual values and estimates of variability.

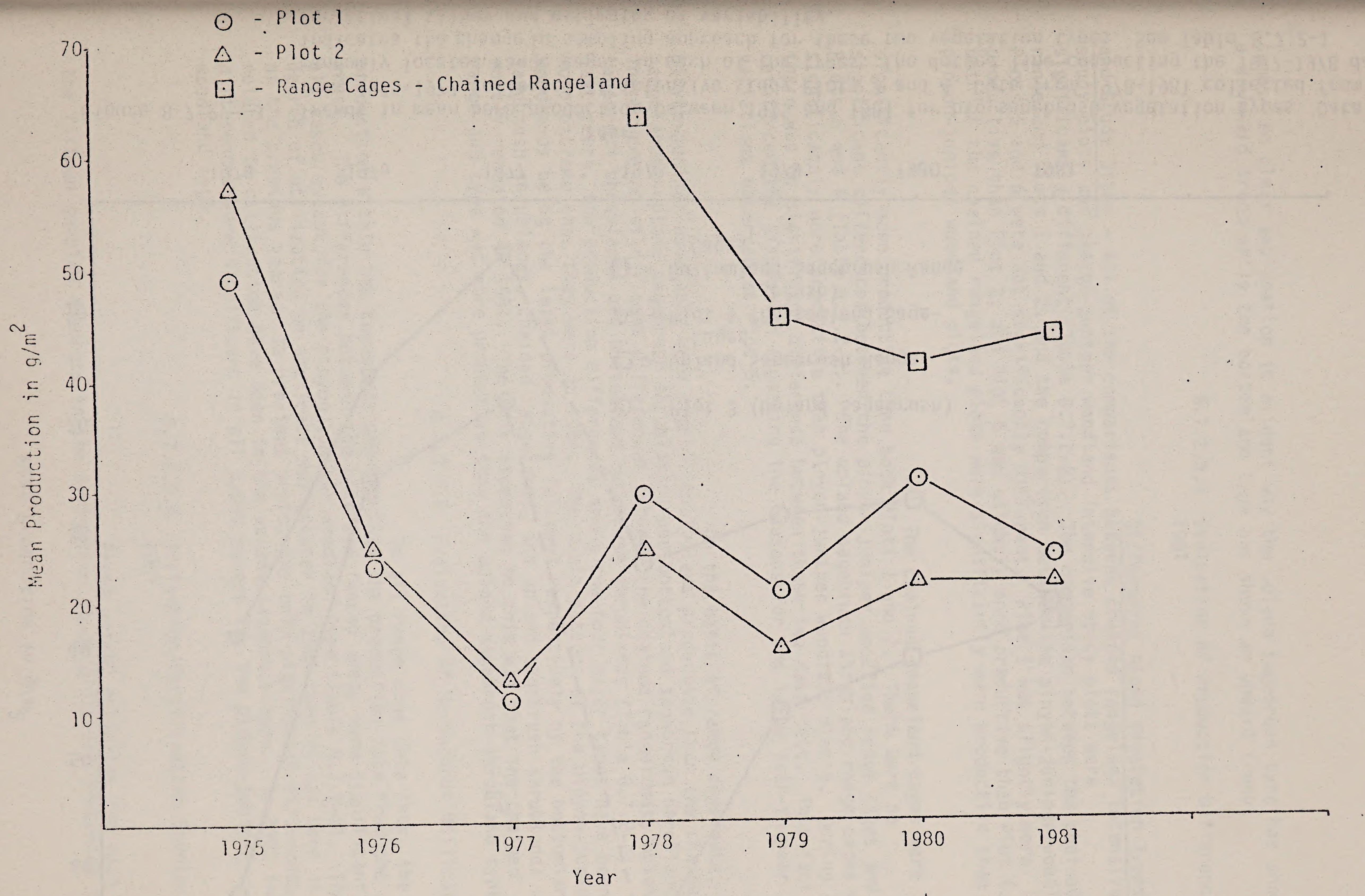


Figure 8.7.2 - 2. Trends in mean herb production between 1975 and 1981 for chained pinyon-juniper rangelands. See Table 8.7.2-1 for actual values and estimates of variability.

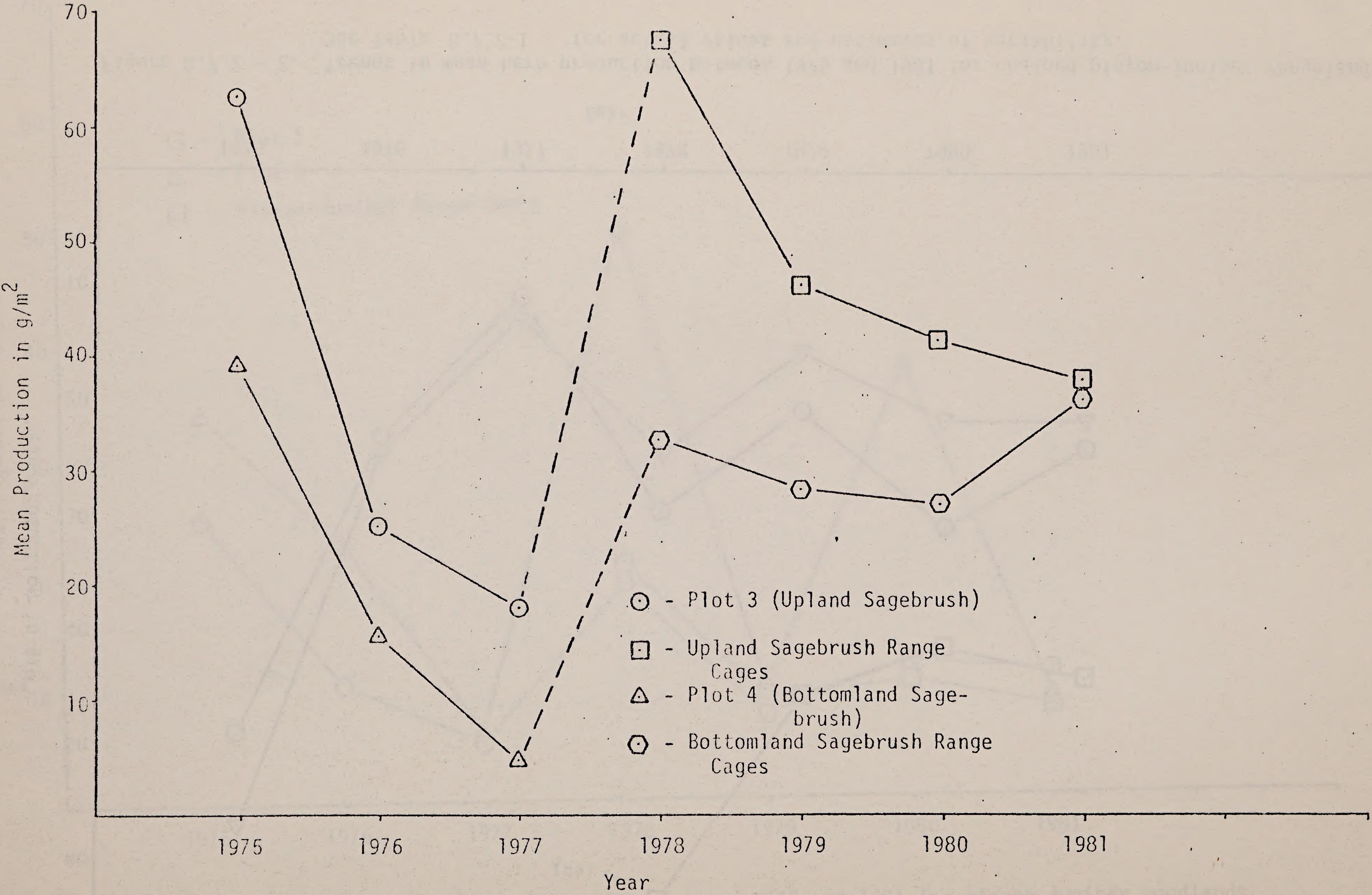


Figure 8.7.2 – 3. Trends in mean herb production between 1975 and 1981 for big sagebrush vegetation types. Data from 1975-1977 collected at intensive study Plots 3 and 4. Data from 1978-1981 collected from randomly located range cages in each of the types. The dotted line connecting the 1977-1978 data indicates the change in sampling approach for these two vegetation types. See Table 8.7.2-1 for actual values and estimates of variability.

same. No clear explanation is evident why the upland sagebrush type has shown a downward trend while the bottomland type has shown an upward trend.

8.7.2.5.4 Evaluation of Production Differences, 1981

Differences Along Vegetation Types and Study Sites - All of the comparisons between chained rangeland intensive study plots and pinyon-juniper woodland intensive study plots were significantly different (Table 8.7.2-2). The comparison between the chained rangeland Plots 1 and 2, and the comparison between the pinyon-juniper woodland Plots 5 and 6 were not significantly different. Plot 1 was slightly more productive than Plot 2, and Plot 5 was slightly more productive than Plot 6. Both of the chained rangeland plots were significantly more productive than the pinyon-juniper woodland plots.

The chained rangeland cages were significantly more productive than both Plots 1 and 2. There were no significant differences between the pinyon-juniper woodland range cages and Plots 5 and 6 (Table 8.7.2-2). The upland sagebrush shrubland range cages were significatnly more productive than pinyon-juniper woodland Plot 6. During 1980 there was no significant difference between these two data sets. This fact reinforces the discussion regarding the reasons for the large year-to-year variations observed at Plot 6.

On the basis of range cage data, the pinyon-juniper woodlands were significantly less productive than the chained rangelands, upland sagebrush shrublands, and bottomland sagebrush shrublands. There were no significant differences between the chained rangelands, upland sagebrush shrublands and bottomland sagebrush shrublands (Table 8.7.2-2). In past years, the production differences among the four major types have been more extreme than they were in 1981. The basic pattern of the pinyon-juniper woodlands being the least productive followed respectively by the bottomland sagebrush shrublands, chained rangelands, and upland sagebrush shrublands was mostly repeated in 1981. The only exception to this was that the chained rangeland type was more productive than the upland sagebrush shrubland type.

8.7.2.5.5 Evaluation of Herbaceous Utilization

In all range cage data sets, the production within the cages was greater than the production data from the open areas. The differences between the open and fenced areas were significant in all cases except for the pinyon-juniper woodland type (Table 8.7.2-2). The degree of utilization on the Tract was greater in 1981 than it has been in any of the previous years. In previous years, the only significant differences related to utilization have been in the upland sagebrush type. In 1981 the differences were significant in all types except for the pinyon-juniper woodland type.

8.7.2.5.6 Irrigation/Fertilization Studies 1981

Fresh weight estimates for each of the fifteen sampled quadrats in the irrigation study plots are presented in

Table 8.7.2 – 2 One-way analysis of variance results for comparison in open and fenced plots and evaluation of differences among sites and vegetation types, 1981. Underlined items in paired tests are those with the greater mean value.

	Calculated F	ν_1*	ν_2*	Critical Region $\alpha = 0.10$ F>	Significance*
DIFFERENCES IN UTILIZATION					
Range Cage Data					
Pinyon-Juniper Open vs. Pinyon Juniper Fenced	1.045	1	28	2.890	NS
Chained Rangeland Open vs. Chained Rangeland Fenced	18.672	1	28	2.890	SIG
Upland Sagebrush Open vs. Upland Sagebrush Fenced	9.628	1	28	2.890	SIG
Bottomland Sagebrush Open vs. Bottomland Sagebrush Fenced	3.124	1	28	2.890	SIG
Irrigated Chained Rangeland Open vs. Irrigated Chained Rangeland Fenced	17.521	1	28	2.890	SIG
DIFFERENCES AMONG VEGETATION TYPES AND STUDY SITES					
Pinyon-Juniper and Chained Rangeland					
Plot 1F vs. Plot 2F	0.590	1	98	2.764	NS
Plot 1F vs. Plot 5F	24.829	1	98	2.764	SIG
Plot 1F vs. Plot 6F	42.962	1	98	2.764	SIG
Plot 2F vs. Plot 5F	14.997	1	98	2.764	SIG
Plot 2F vs. Plot 6F	26.785	1	98	2.764	SIG
Plot 5F vs. Plot 6F	1.429	1	98	2.764	NS
Based on Range Cage Data					
Pinyon Juniper vs. Chained Rangeland	37.523	1	28	2.890	SIG
Pinyon-Juniper vs. Upland Sagebrush	90.670	1	28	2.890	SIG

Table 8.7.2 - 2 (contd.) Comparison in open and fenced plots and evaluation of differences among sites and vegetation types, 1981.

	Calculated F	ν_1*	ν_2*	Critical Region $\alpha = 0.10$ F>	Significance*
Based on Range Cage Data					
Pinyon-Juniper vs. Bottomland Sagebrush	6.926	1	28	2.890	SIG
Chained Rangeland vs. Upland Sagebrush	0.830	1	28	2.890	NS
Chained Rangeland vs. Bottomland Sagebrush	0.766	1	28	2.890	NS
Upland Sagebrush vs. Bottomland Sagebrush	0.161	1	28	2.890	NS
Chained Rangeland vs. Irrigated Chained Rangeland	24.324	1	28	2.890	SIG
Based on Range Cage and Intensive Study Plot Data					
Plot 1 vs. Chained Rangeland Cages	15.778	1	63	2.789	SIG
Plot 2 vs. Chained Rangeland Cages	18.320	1	63	2.789	SIG
Plot 5 vs. Pinyon-Juniper Cages	1.127	1	63	2.789	NS
Plot 6 vs. Pinyon-Juniper Cages	0.502	1	63	2.789	NS
Plot 6 vs. Upland Sagebrush Cages	215.620	1	63	2.789	SIG

*NS = Not Significant
SIG = Significant
ν_1 = degrees of freedom for numerator
ν_2 = degrees of freedom for denominator

Table A8.7.2-21, and dry weights for the clipped plots are presented in Table A8.7.2-22. the regression equations for converting the fresh weight estimates to oven dry weights are presented in Table A8.7.2-23 and Table A8.7.2-24.

Mean values for each of the fertilized treatments ranged from 42.2 g/m^2 to 138.6 g/m^2 (Table A8.7.2-25). The highest mean value was obtained for the treatment block which received 18 hours of irrigation and was fertilized with 200 lbs/acre of nitrogen and 100 lbs/acre of phosphate. This was the highest application of both fertilizer and irrigation. The lowest value came from the treatment block which received the lowest application of fertilizer and irrigation. Within each of the fertilization treatments, the one receiving 18 hours of irrigation was always higher. Production in the areas which received fertilization in both 1980 and 1981 was always greater than the production in the areas which were fertilized in only 1980. In all but one case the fertilized and irrigated plots had production values greater than the non-fertilized areas. In general, the data are consistent with the design and anticipated results of the experiment. In addition to the data from the treatment blocks themselves, fifteen range cages were set out in the irrigated chained rangeland areas. Oven dry weights for these cages are presented in Table A8.7.2-26 and mean production values are presented in Table A8.7.2-27. Mean production in these areas was 127.8 g/m^2, which was nearly as great as the highest fertilization and irrigation treatment. The value was also significantly greater than the non-irrigated chained rangeland type (Table 8.7.2-2). Utilization in these areas was also significant (Table 8.7.2-2).

Evaluation of the effects of fertilization and irrigation was accomplished using a three-way analysis of variance which examined the following factors: fertilization rate, fertilizer application frequency, and irrigation rate. The results of the analysis of variance are presented in Table 8.7.2-3. All three of the factors produced significant differences in herbaceous production. The interaction of fertilization rate and irrigation rate, and the interaction of fertilization rate and application frequency were also significant. The interaction of irrigation rate and application frequency, and the interaction of all three factors were not significant. In terms of using fertilization and irrigation as a means of mitigating habitat loss, several important results can be seen. Based on the results of the three-way analysis of variance, production can be enhanced by: 1) irrigating the chained rangelands, 2) fertilizing the chained rangelands once and then irrigating, or 3) fertilizing the chained rangelands twice and then irrigating. Irrigation and fertilization combined will significantly increase the production over those areas which are simply irrigated and fertilizing twice will significantly increase the production over those areas fertilized only once. Irrigation for 18 hours will significantly increase the production over those areas irrigated for only 12 hours. Using this information it should be possible to formulate a reasonable approach to mitigating habitat losses using fertilization and irrigation.

The fact that the range cage data from the irrigated chained rangelands showed production values nearly as great as those from the highest fertilization and irrigation treatment does not invalidate the results of the analysis of variance. The site where the irrigated chained rangeland cages are located appears to be somewhat more

Table 8.7.2 – 3. Results of the three-way analysis of variance test for evaluating the effects of fertilization rate, irrigation rate and fertilization frequency.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F	Significance*
Subgroups					
A Fertilization Rate (FR)	2	732.03	366.01	62.35	SIG
B Irrigation Rate (IR)	1	398.01	398.01	67.80	SIG
C Fertilization Frequency (FF)	1	307.80	307.80	52.44	SIG
AxB FRxIR	2	166.07	83.03	14.14	SIG
AxC FRxFF	2	175.25	87.63	14.93	SIG
BxC IRxFF	1	9.55	9.55	1.63	NS
AxBxC FRxIRxFF	2	5.66	2.83	0.48	NS
Within Subgroups (Error)	168	986.56	5.87		
Total	179	2780.93			

$F_{0.05\ [1,\infty]} = 3.84$ $F_{0.05\ [2,\infty]} = 3.00$

*SIG = Significant at α = 0.05
NS = Not significant at α = 0.05

productive than the areas where the fertilization treatment plots are located. The range cage site was also more productive than the treatment plots in 1980.

8.7.2.6 Conclusions

Based on the data collected during 1981 several conclusions may be drawn:

1. The patterns of herbaceous production on the Tract are essentially the same as those observed during the baseline and previous years.

2. Herbaceous utilization during 1981 was greater than during any other year of monitoring. This appears to be related to a longer period of spring grazing on the Tract.

3. The non-significant differences between the production at Plots 1 and 2 and at Plots 5 and 6 suggest that development of the site is not having an impact on these areas. Any observed differences are most likely related to natural variation rather than being related to site development.

4. Some of the year to year variation noted at the intensive study plots may be related to plot location rather than being related to actual production differences.

5. Based on the analysis of variance results, irrigation rate, fertilization rate, and application frequency can all cause significant differences in herbaceous production.

8.7.3 Shrub Productivity and Utilization

This section has been incorporated into Section 8.2.2 entitled Browse Production and Utilization in this report.

8.7.4 General Vegetation Conditions Study

This section has been incorporated into Section 4.2 utilizing Landsat.

8.7.5 Microclimatic Studies

8.7.5.1 Scope

Studies on microclimatic parameters on the C-b Tract provide data that are useful in assessing changes in vegetation production and structure, animal populations, or animal activity patterns, and may also be correlated with changes in functional components of the C.B. ecosystem that may occur as a result of oil shale development.

8.7.5.2 Objectives

The objectives are to measure and evaluate time trends in climatic variables of surface and air temperatures, surface precipitation, and snow depth at specific locations within the various

vegetative communities; to provide data for ecosystem interrelationship studies.

8.7.5.3 Experimental Design

Five microclimatic stations are located in development sites and five in control sites. The locations of these ten sites (See Stations BC01 through BC09 and BC13 on the jacket map, Exhibit C) are the same as baseline locations. Therefore, data from March 1975 through the present can be compared. Each station is monitored twice monthly for the following parameters:

Microclimate Station Locations		Parameters Measured at each Station
BC01	Chained Pinyon-Juniper Rangeland	Air Temperature,
BC02	Chained Pinyon-Juniper Rangeland, Vegetation Plot 2	Soil Temperature,
BC03	Plateau Sagebrush, Vegetation Plot 3	Surface
BC04	Valley Bottom Sagebrush, Vegetation Plot 4	Precipitation,
BC05	Pinyon-Juniper Woodland, Vegetation Plot 5	Snow Depth and
BC06	Pinyon-Juniper Woodland, Vegetation Plot 6	Moisture Content
BC07	Chained Pinyon-Juniper Rangeland (Animal Trapping Transect)	
BC08	Bunchgrass Community, South-facing Slope	
BC09	Valley Bottom Sagebrush, Mouth of Sorghum Gulch	
BC13	Mixed Mountain Shrubland, North-facing Slope	

All temperature readings consist of maximum and minimum readings for two-week periods. Precipitation is measured only during the growing season, March through October. Therefore, precipitation data from meteorology stations AB20 and AB23 are utilized for winter-month readings (November-February) for valley and pinyon-juniper microclimate stations. Snow measurements are obtained approximately from November-February.

8.7.5.4 Method of Analysis

Methods of analysis include time series plots contained in the Supplement(s) to the Development Monitoring (data) Reports for precipitation, snow depth, and maximum and minimum temperatures, and correlations of microclimatic data with plant and wildlife data. The reader should also consult Subsection 6.3.1, Climatological Records, for additional tables, time series plots, and histograms.

8.7.5.5 Discussion and Results

Time series plots for 1981 microclimate data are presented in the Detailed Monitoring Report #7. These plots were compared to the time series plots from previous years. Observations resulting from this analysis are:

Spring and summer precipitation was comparable to previous years, but fall and winter precipitation were slightly higher than in 1980.

Snow depths for the 1981 January-March period were less than for the same period in 1980.

1981 Had more frost free days than 1980.

8.7.5.6 Conclusions

The following conclusions were drawn from visual analysis:

a. Snow measurements were higher for November and December 1981 than for the same time period in 1980. The 1980-81 Winter seemed to have less snowfall than the 1981-82 Winter.
b. Precipitation for 1981 was similar to previous years.
c. Temperatures for 1981 were similar to previous years with the exception that 1981 had more frost free days than 1980.

8.8 Threatened and Endangered Species

No threatened or endangered species were seen on C-b Tract. Bald eagles were occasionally sighted in the general vicinity. Since the area is only marginal winter habitat and the bald eagles are only occasional visitors, no further action will be taken except for continuing to monitor their presence.

Sandhill cranes were again observed in the general Tract vicinity. However, no sandhill cranes were observed on Tract so we will continue routine monitoring for their presence.

No threatened or endangered plants were found on or near Tract C-b. New plants are continually being added to the permanent herbarium on Tract.

In conjunction with the numerous biological studies that will be conducted on and near Tract C-b during all parts of the year, observations confirmed by staff field biologists of any threatened or endangered species will be reported to the OSO (Oil Shale Office). Appropriate studies to determine significance of a sighting will then be initiated as determined jointly by C.B. and OSO personnel.

8.9 Revegetation

Revegetation monitoring is conducted on sites which have undergone surface disturbance and on processed and raw shale disposal sites. Monitoring techniques assess the progress of reestablished vegetation. Monitoring is limited to revegetated areas of at least one acre in size.

8.9.1 Composition and Production

Sampling of revegetated areas is initiated during the third growing season. Past revegetation experiences (drill pads seeded in 1975 and 1976) have shown that weedy annuals, such as Russian thistle and Kochia, tend to dominate the sites for the first two years, and the desired perennial grasses, forbs and shrubs of the seed mixture start dominating the third year. Visual observations of the sites is utilized until sampling is initiated.

8.9.1.1 Scope

Monitoring of revegetated areas is similar to the monitoring of the terrestrial vegetation as discussed in Section 8.7. Each revegetated site is sampled once during the growing season near the time of peak growth (about mid-July). Monitoring includes inventory measurements of species frequency; percent cover, both herbaceous, shrub and tree; species diversity; and herbaceous biomass production.

The revegetated areas monitored in 1981 are the topsoil storage piles which were seeded in the Fall of 1978.

8.9.1.2 Objectives

The objective of the revegetation program is not a duplication of the original vegetation community (predisturbed vegetation) but rather to establish a similar vegetation structure, similar in cover and diversity, and at least as productive. The monitoring of revegetated areas, in conjunction with baseline monitoring and ongoing monitoring of terrestial vegetation will determine if that objective is met.

8.9.1.3 Experimental Design

Sampling for species frequency and percent cover is accomplished through the use of ocular estimation. In each revegetated topsoil storage area a grid of 25 one-square-meter quadrats is randomly located for sampling. The center of each quadrat is permanently marked with a stake so that the same area will be sampled each year. An estimation of cover is made for individual species, rock, bare ground, litter, lichens and mosses.

As the shrub and tree seedlings become more established and reach a height greater than 0.25 meters, they will be sampled using the line-strip method of sampling described in Section 8.7.1.3.

Estimates of percent cover are used to determine the diversity of the vegetation.

A double sampling technique is used in order to determine herbaceous production. Twenty-five one-square-meter quadrats are sampled on the topsoil piles. At the time of estimated peak standing crop an ocular estimate of the current year's growth of the major vegetation fractions for each quadrat is made. Additionally, seven of the quadrats are clipped and major vegetation fractions bagged. The major vegetation fractions are: the wheatgrasses, Indian ricegrass, wildrye grasses, other perennial grasses, perennial legumes, other perennial forbs, sweet clover, cheatgrass, annual grasses, annual forbs, and half shrubs. The clipped fractions are returned to the lab, oven dried and weighed to the nearest 0.01 gram. A correlation between oven dry weights and ocular estimates is made and ocular estimates are adjusted accordingly.

8.9.1.4 Method of Analysis

Reference areas used for comparison of revegetated areas to undisturbed areas are the intensive study plots described

in Section 8.7. The particular study plot to be used for comparison is dependent on what particular vegetation type occupied the revegetated area prior to disturbance, i.e., if the revegetated area was in the chained pinyon-juniper vegetation type prior to disturbance, then the study plot in the chained vegetation type is used for reference. In the case of herbaceous production, both vegetation plots and range cages (caged quadrats only) are used for comparison. In the case of the topsoil piles sampled in 1981 the intensive study plots and range cages in the chained pinyon-juniper rangeland are used for comparison. These are Plots 1 and 2 (BJ01 and BJ02) and range cage numbers 61-75.

The evaluation of revegetation success for cover and production is a one tailed test for statistical significance. The test is one tailed because we are only interested in knowing if the revegetation efforts have met or exceeded the standard (reference area). We are not concerned with the amount the standard was exceeded, only that a standard has been met. Therefore, the evaluation requires a statistical test only when the revegetated mean is less than or equal to the standard.

The hypotheses to be evaluated for both cover and herbaceous production are:

H_0: Revegetated area production (cover) is greater than or equal to that for the reference area

H_a: Revegetated area production (cover) is less than that for reference area

The calculated means for both cover and herbaceous production, and for both revegetated and reference areas are used.

In the case where the revegetated area is less than the reference area a t-test comparison is used to evaluate revegetation success. The form of the equation is:

$$t_e = \frac{\underline{X}_1 - \underline{X}_2}{\dfrac{S_1^2}{n_1} + \dfrac{S_2^2}{n_2}}$$

(Cochran and Cox, (1957)

where:

t_e = calculated estimate of t
X = mean for revegetated and reference area
S^2 = variance of the mean
n = number of samples.

The t-test equation calculates an estimated t value (t_e). The estimated value is compared to a t-table value (one tail) to

evaluate vegetation success. If t_e is less than or equal to the t-table value revegetation success is confirmed (H_0 is accepted).

The Shannon-Weiner Index, as proposed by Pielou (1975), is used to evaluate species diversity. The equation:

$$H = - P_i \sum_i \log P_i$$

Where H = the diversity index
$P_i = N_i/N$
N_i = the importance measure for species $_i$, and
N = the sum of all species importance measures.
The index is calculated by using vegetation cover.

The Shannon-Weiner Index (H) is the sum of the species contributions for an area. The relative importance of each species in the area can be expressed as the proportion or the percentage of the H value contributed by each species. Therefore, a diversity standard for the revegetated area can be determined by evaluating the distribtuion of species importance in the reference area vegetation.

A level of the percentage of the H value is selected for the diversity standard from the reference area data. This will determine the amount of diversity to be attained in reclamation efforts. The level is determined by the percentage of the H value contributed by the principle species of the area. Each of the identified principle species will contribute a range of percent to the species diversity of the reference area. Hence, the overall revegetation strategy, in order to meet diversity requirements, will be to establish communities on the disturbed area that contain at least the same number of principle species and life form identified in the reference area diversity calculations. The principle species of the revegetated area should contribute the same range of percent to the diversity index of the revegetated areas as the principle species contributed to the reference area. For example, a reference area has five species that contribute 70 percent of the reference area diversity and their range of percent diversity is 5 to 30 percent. For the revegetated area to meet the diversity requriements it must be composed of a vegetation community that has at least five species that contribute 70 percent of the diversity whose individual values range between 5 and 30 percent. If only one or two species accounts for 80 percent of the diversity value in the revegetated community, the diversity criterion has been met on a percentage basis, but no species should have exceeded 30 percent contribution to the diversity value. Hence, the revegetation success criterion, as measured by diversity, has not been met.

8.9.1.5 Discussion and Results

There are two sources of possible error involved in monitoring vegetation. First, in visual evaluation of species cover it is very difficult to be totally consistent from year to year and even from quadrat to quadrat, even if the data are recorded by the same observer. Second, difficulties in species recognition constitute a source of error which is difficult to eliminate. This is especially true for grass species in vegetative condition. Species recognition is manifested in both cover and production data. Visual estimates affect only the cover data.

The most prevalent species found on the topsoil piles include the wheatgrasses, crested wheatgrass (Agropyron cristatum), pubescent wheatgrass (A. smithii), beardless bluebunch wheatgrass (A. spicatum var inerme), Utah sweetvetch (Hedysarum boreale), sweetclover (Melilotus spp.), Russian thistle (Salsoa iberica), and Kochia (Kochia iranica). These species had a frequency of 50 percent or greater.

The species having the greatest amount of ground cover include pubescent wheatgrass (2.52%), western wheatgrass (4.56%), Utah sweetvetch (4.28%) and sweetclover (4.22%). Total mean cover in the herb layer was 22.1 percent. Litter had a mean cover of 79.0 percent, and bare ground had a mean cover of 18.28 percent. The mean number of species per square meter was 6.68.

The mean total production of the topsoil piles was 113.7 grams/m^2 (1014 lbs/acre). Most of the production is attributable to the wheatgrasses, Utah sweetvetch and sweetclover.

The cover, frequency and production data from the topsoil piles are presented in Tables A8.9.1-1 through A8.9.1-5 of Volume 2A of this Annual Report.

Evaluation of Cover - Reference areas used for comparison of the revegetated topsoil piles to undisturbed areas are the fenced intensive study plots 1-F and 2-F (BJ01 and BJ02). Both of these plots were sampled during 1981. Plot 1-F had a total herb cover of 12.9 percent, and total woody cover in the herb layer was 0.3 percent for a total herbaceous cover of 13.2 percent. Plot 2-F had a total herb cover of 7.4 percent, and total woody cover in the herbaceous layer was 0.1 percent for a total herbaceous cover of 7.5 percent. Total herbaceous cover for the topsoil piles was 22.1 percent.

Since the total herbaceous cover for the topsoil pile is greater than the total herbaceous cover of both plots 1-F and 2-F no test is needed, and H_0 is accepted.

A comparison of cover in the shrub layer is not done here because the shrub species on the topsoil piles have not yet become established enough to be sampled for shrub layer cover.

Evaluation of Diversity - Reference areas used for comparison of diversity are the same ones used in the percent cover evaluation (Plots 1-F and 2-F). The reference areas have seven species that contribute 70 percent of the reference area diversity in the herbaceous layer and their range of percent diversity is 5 to 16 percent. The revegetated topsoil piles have eight species that contribute to at least 70 percent of the reference area diversity in the herbaceous layer and their range of percent diversity is also 5 to 16 percent. Diversity calculation data are presented in Tables A8.9.1-6 and A8.9.1-7.

A comparison involving the shrub layer cover component was not done because the shrubs on the revegetated topsoil piles have not become sufficiently established to sample.

Evaluation of Productivity - Reference areas used for comparison of productivity are study Plots 1 and 2 (BJ21 and BJ22) and the range cages of the chained pinyon-juniper rangelands (#'s 61-75, caged quadrats only).

The herbaceous productivity of the revegetated topsoil piles was 113.7 g/m^2 (1014 lbs/acre). This compares to productivity of Plot 1 of 23.69 g/m^2 (211 lbs/acre); Plot 2 of 21.27 g/m^2 (193 lbs/acre) and the range caes of 43.63 g/m^2 (389 lbs/acre). The productivity of the topsoil piles is greater than that of the reference areas, therefore no test is required.

8.9.1.6 Conclusions

Revegetation success of the topsoil piles has been met relative to herbaceous cover, diversity and productivity. However the shrubs of the topsoil piles have not become sufficiently established to meet the criteria needed for success concerning the shrub layer components of cover and diversity. Therefore the overall success of revegetation of the topsoil piles has yet to be met.

Since this is only the third full growing season for the vegetation of the topsoil piles the above conclusions should be expected.

8.10 Systems Dependent Monitoring

Additional aquatic studies, sublethal biochemical studies, and soil plant elemental analysis, are potential system dependent monitoring programs. They were not "triggered" by indicator variables, and therefore no monitoring for them was accomplished during 1981. However, additional monitoring in areas of the land application (sprinkler) system is systems dependent and is discussed in Sections 8.7.1, 8.7.2 and 8.11.3.

8.11 Special Projects

The main purposes of these special projects are to mitigate effects that oil shale development may have on fish and wildlife and/or to fulfill Lease requirements. These projects will be continued on a yearly basis depending upon the success or usefulness of each individual project.

8.11.1 Brush Beating Project

Two sagebrush gulches (Gardenhire and Oldland) were brush beaten in 1979 as a mitigation project to: (1) improve forage for wildlife and livestock, (2) reduce deer winter range use by livestock, and (3) reduce the deer roadkill. In addition, catch basins were built to collect spring runoff and possibly reduce the number of deer crossing the highway for water.

Nine pellet-group transects (BA41-49) were established to evaluate the deer habitat enhancement program. Four deer pellet group transects (BA41, 42, 45, 46) were subsequently set out within these brush-beaten areas. Five additional transects were established in similar valley sagebrush habitat in the nearby vicinity.

A comparison of differences between deer pellet group densities in brush-beaten areas with control areas (Table 8.11.1-1) suggests that fewer deer occurred in the brush-beaten area during this first winter period. This conclusion is tentative, however, since three important considerations must be taken into account: 1) relative differences in deer use among the locations prior to brush beating are not known; 2) the significant second level (among transect) F-test (Table 8.11.1-1) demonstrates that considerable variation occurs among transects within both the treatment and control groups; this can be readily seen by examining the differences among the transect means; 3) the winter of 1980-81 was exceptionally mild, and comparatively few deer occupied in the low-elevation valley sagebrush habitats (see road count results, Figure 8.2.3-1).

Lagomorph abundance data were also collected on the nine deer transects (see Table 8.3.2-1). Counts seemed to be higher in the undisturbed areas which was probably due to the lack of sufficient tall cover in the brush beaten areas.

Vegetation sampling consisted of sampling herbaceous species and shrubs, with the exception of sagebrush (Artemisia tridentata), for species frequency and annual production. Sampling was done along randomly located transect lines, one each in both gulches where brush beating occurred and one control transect (no brush beating). Each transect consisted of sampling 25 one-square-meter quadrats.

Frequency was determined for individual species encountered at each site. Mean annual production was determined for individual species as well as entire sites. Production was determined using a double sampling approach described in Section 8.7.2.3. The data and results are listed in Tables A8.11.1-1 through A8.11.1-12 of the Appendix.

Mean herbaceous production for the brush beating sites was more than twice that of the mean herbaceous production of the control site.

Table 8.11.1-1 Comparisons of pellet group counts in brush-beaten valley sagebrush with control areas.

RESULTS OF HIERARCHIAL ANOVA

Source of Variation	DF	MS	F	Variance Components
Between brush-beaten and control areas	1	3.68	7.7**	39.5%
Among transects	7	0.48	14.5***	24.4%
Among quadrats	171	0.03		36.1%

Transect means ± SE (n):

Brush-beaten		Control	
BA41	20 ± 11.7 (20)	BA43	5 ± 5.0 (20)
BA42	15 ± 8.2 (20)	BA44	275 ± 36.2 (20)
BA45	30 ± 16.4 (20)	BA47	205 ± 42.0 (20)
BA46	5 ± 5.0 (20)	BA48	230 ± 42.4 (20)
		BA49	110 ± 21.6 (20)

Conclusion:

Pellet group densities in control areas were significantly higher than in brush-beaten areas. See text for discussion.

** significance at $\alpha = 0.05$

*** significance at $\alpha = 0.01$

Mean herbaceous production in Oldland Gulch was 63.07 g/m^2 (562 lbs/acre), Gardenhire Gulch production was 68.73 g/m^2 (613 lbs/acre). Mean production in the control site was 25.41 g/m^2 (226 lbs/acre).

Species frequency was similar for both control and developmental sites.

Results seem to indicate that open canopy cover of the brush beaten areas increases herbaceous species production. An assessment of the efficacy of the program to mule deer will probably require several additional years of study before more definitive conclusions can be made.

8.11.2 Raw Shale Lysimeter Tests

8.11.2.1 Introduction and Scope

Raw mined shale piled on the ground surface constitutes a relatively permeable mass of particles ranging in size from silt and clay to boulders that readily accommodates infiltration of incident precipitation. A portion of the waters that infiltrate the piles is evaporated and a portion percolates downward and eventually becomes seepage from the pile. The fragmented raw shale stored on the surface resides in a hydrogeochemical environment different from that before mining and many fresh surfaces are exposed to contact by water and air.

Fragmentation of raw shale and placement in a different hydrogeochemical environment creates the potential for the release of undesirable chemicals into waters contacting the materials. A previous study conducted in the laboratory (McWhorter, (1980) suggested that the potential was sufficient to warrant a field data collection program. A cooperative field study was initiated on April 1, 1980. The major objective was to determine the quantity of leachate generated in storage piles of raw mined oil shale. A subsidiary objective was to compare the field data with that generated from laboratory columns to assist in the assessment of leaching columns as a useful test of potential chemical release.

This study was originally conceived as a cooperative project among Colorado State University, U.S. Environmental Protection Agency, the U.S.G.S. Area Oil Shale Office and the Rio Blanco Oil Shale Company. The first field leachate collection systems were installed on Federal Lease Tract C-a under that agreement and the first leachate sample was collected in August, 1980. Subsequently, the scope of work was broadened to include a similar installation on Federal Lease Tract C-b in cooperation with Cathedral Bluffs Shale Oil Company. The leachate collection system at C.B. was constructed during Fall, 1980. Data from both Tracts were collected during 1981. This report summarizes only the C.B. results; the complete study is reported in Quality and Quantity of Leachate from Raw Mined Oil Shale by David B. McWhorter, April 1982 (Interim Report under Cooperative Agreement CR-807513).

8.11.2.2 Experimental Design

Seepage of percolate through the raw shale piles occurs at less than full saturation as dictated by the fact that the rate of

supply from precipitation is intermittent and nominally less than the saturated hydraulic conductivity of the materials. The pressure of the percolating solution is less than atmospheric under such circumstances. Even though methods for measuring and sampling seepage at negative gauge pressures are available, the decision was made to utilize an impervious surface buried in the pile as a collection mechanism. The rationale included the fact that the materials are quite coarse and, therefore, little change in the flow pattern would be induced by artificially creating a perched water table on the impervious surface of the collector.

The raw shale lysimeters were constructed in November and December 1980. Each of the lysimeters has a collecting surface area measuring 10' x 10'. The three collectors were covered with raw shale mined from the Intermediate Void Level of the Production Shaft and the Upper Void Level of the Ventilation/Escape Shaft to depths to 10, 15, and 20 feet, respectively. The three collectors are constructed entirely of teflon components to minimize contamination (see Figure 8.11.2-1).

The material from the V/E Shaft came from an interval between elevations 5245 and 5265 feet. The extraction interval from the Service Shaft was 5340-5360. It is estimated that the final mixture of materials over the collectors is 40% from the V/E Shaft and 60% from the Service Shaft.

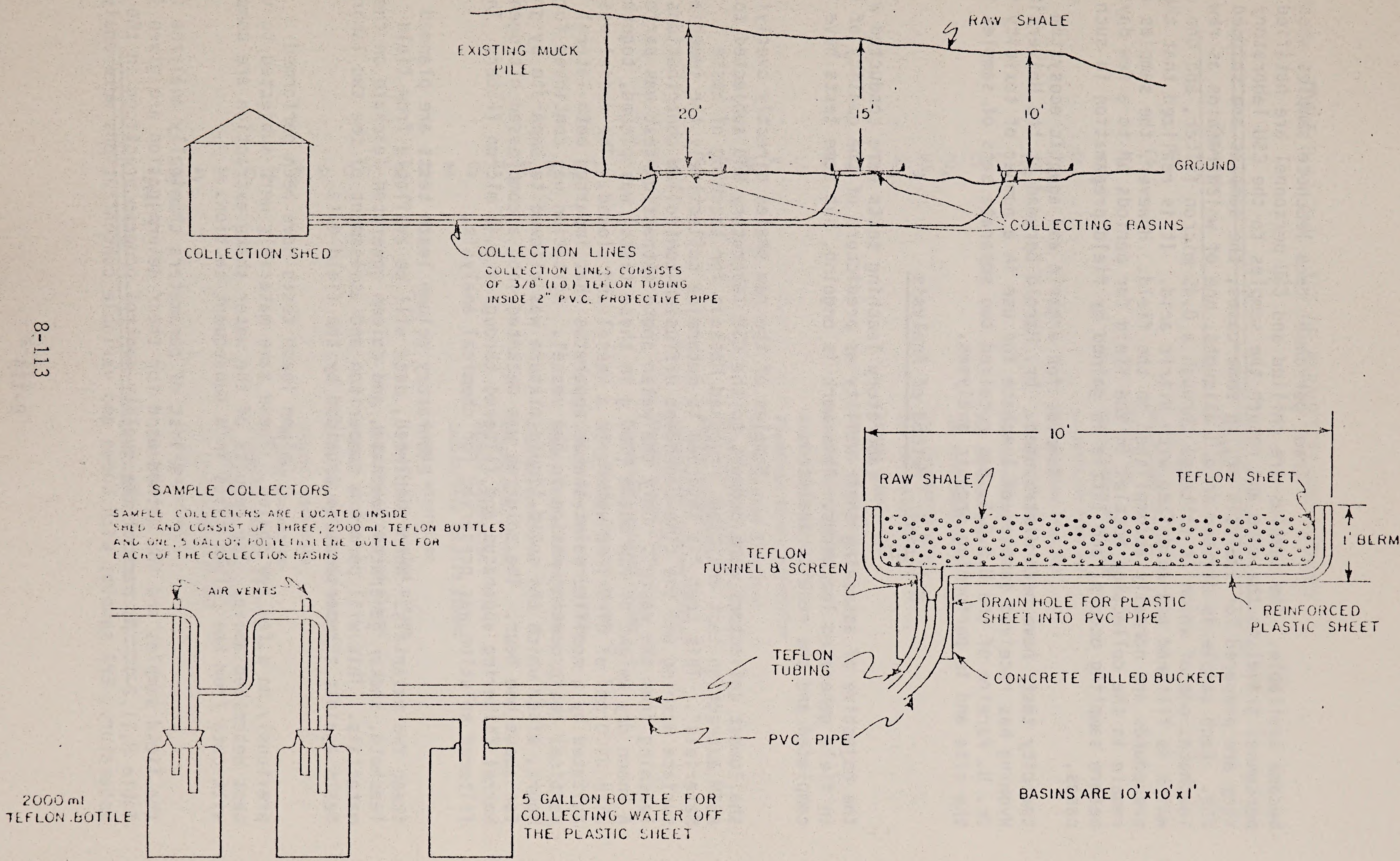
Precipitation is measured with a recording rain gauge. This gauge is immediately adjacent to the 10 foot collector. Tract personnel collect the charts, and service and maintain these gauges. Copies of the charts are sent to Colorado State University. Any differences in precipitation as interpreted by Tract and CSU personnel are reconciled and a final record of cumulative precipitation is prepared.

All leachate collected on the teflon or polyethylene sheets is routed to collection vessels through drain lines. Leachate generation is sporadic and in response to random precipitation and snow melt. No attempt is made to measure instantaneous seepage rates. Rather a record of cumulative volume of leachate for each collector is prepared. Members of the Tract staff monitor the volumes of leachate in all of the collection vessels. From time-to-time CSU personnel are on site and make the measurements, but usually the Tract personnel forward the volume measurements to Fort Collins for tabulation.

Sampling for chemical analysis is concentrated on the teflon bottles; these bottles are emptied and volumes recorded on a very frequent basis relative to two overflow bottles. Volumes are recorded only when the bottles are emptied. This procedure sometimes results in abrupt increases in leachate volume that are related to the time at which the vessels are emptied rather than to a flow event. The overall correspondence between precipitation and leachate generation is not masked by this procedure (as is demonstrated subsequently), but instantaneous flow rates calculated from the record of cumulative leachate volume would be unreliable.

Field temperature and EC are measured at the time the bottles are sampled for chemical analysis.

FIGURE 8.11.2-1 RAW SHALE LEACHATE STUDY SITE



Tract personnel take leachate samples when they become available. The samples are chilled and CSU personnel are notified. CSU personnel travel to the site and return the samples to the CSU laboratory where they are prepared for analysis or, in some cases, the samples are shipped to CSU. Each sample is divided into 3 aliquots, one of which remains as raw leachate, one of which is filtered through a 0.45 micron filter, and one of which is filtered and acidified with nitric acid. It is realized that these procedures are normally accomplished in the field. However, the samples often remain in the collection bottles in the field for periods up to a few days before sampling occurs, and little is gained by field preparation in such cases.

Samples for organic and aquatic ecosystem toxicity tests have been distributed. Dr. Harold Bergman at the University of Wyoming has received samples of leachate for use in a number of toxicity tests. Dr. W. Pereira of the U.S.G.S. has received two separate sets of samples from the site and is performing organic analyses.

8.11.2.3 Method of Analysis

Laboratory leaching tests were conducted with the objective of assessing their utility as predictors of the quality of waters in field generated leachates. This work is ongoing, but some tests have been completed and the results analyzed.

Samples of the raw shales directly overlying the shallowest collectors were brought to the CSU laboratory and subjected to the ASTM extraction test entitled "Proposed Methods for Leaching of Waste Materials". This test "is intended to determine collectively the immediate surface washing and the time-dependent diffusion-controlled contributions to leaching from the waste". Only the water shake extraction test was performed. A known dry weight of raw shale (700 g in these tests) was placed, together with 2800 cm^3 of distilled water, in a vessel and closed. The vessel was agitated by a modified paint-shaker apparatus that imparted both lateral and vertical reciprocating motion to the vessel. Agitation was continued for 48 hours, after which the solid-liquid mixture was allowed to separate by gravity for about one hour. The solution was decanted into a compressed nitrogen barrel filtering apparatus and filtered through a 0.45 micron filter. The filtered solution was preserved for chemical analysis.

Laboratory column leach tests are planned for these two materials. When completed, data will be available from field leachate, shaker generated leachate, and column generated leachate on the same materials. This will permit a comparison and assessment of the two laboratory tests against the perspective provided by the field data.

Column leach tests have been performed previously on a few raw shales. These same materials were subjected to the test described above. The results of the water shake extraction are compared with data from the column tests in a subsequent section.

A list of parameters chemically analyzed from the field samples and the method used for their determination are given in Table 8.11.2-1. As part of the quality control program practiced in the laboratory, EPA samples with known and variable concentrations were analyzed

TABLE 8.11.2-1 LIST OF PARAMETERS AND METHODS

Parameter	Method
pH	Electrode
EC	Wheatstone bridge
ALK	Titration
HCO_3	Calculation from ALK
CO_3	Calculation from ALK
H_2CO_3	Calculation from ALK
TDS	At 180° gravimetric
F	Ion chromatography
Cl	Ion chromatography
PO_4	Ion chromatography
NO_3	Ion chromatography
SO_4	Ion chromatography
Zn	Atomic adsorption
Fe	Atomic adsorption
Co	Atomic adsorption
Li	Atomic adsorption
V	Flameless atomic adsorption
NH_3	Ion selective electrode
B	Inductively coupled plasma
Cd	Atomic adsorption
Be	Inductively coupled plasma
Mg	Atomic adsorption
P	Inductively coupled plasma
Si	Inductively coupled plasma
Mo	Inductively coupled plasma
Mn	Inductively coupled plasma
Ni	Atomic adsorption
Na	Atomic adsorption
Cu	Atomic adsorption
Al	Inductively coupled plasma
Ca	Atomic adsorption
Ba	Inductively coupled plasma
K	Inductively coupled plasma
Cr	Atomic adsorption
Sr	Inductively coupled plasma
Pb	Atomic adsorption
Ag	Atomic adsorption
Tl	Flameless atomic adsorption
Se	AA (Hydridegeneration)
As	AA (Hydridegeneration)
Hg	Cold vapor cell
Total N	Kejhdahl

with each group of samples. If results for the knowns deviated more than 10 percent from the true value, analyses were repeated until satisfactory agreement was obtained. Samples were occasionally spiked with a known concentration, and multiple standard additions were run to check completeness and determine sample matrix effects. Standards are run and instruments are recalibrated with a frequency sufficient to detect and correct instrument drift and other problems that sometimes arise.

8.11.2.4 Results and Discussion

Precipitation and Leachate Volume - Figure 8.11.2-2 shows the cumulative volume of leachate measured from the collector buried at a depth of 15 feet on the C-b Tract. Also shown for comparison is the cumulative precipitation, but with a lag of some 5-10 days. A total of 6.39 cm of leachate was measured, representing 21 percent of the precipitation measured over the same time period. The 10 foot and 20 foot collectors produced 4.36 cm (14 percent) and 6.15 cm (20 percent) of leachate, respectively. Such volumes of percolate are large in the perspective of anticipated natural recharge rates for the area. The relatively large volumes are attributed to the fact that the piles are very previous and bare of vegetation, both of which tend to minimize runoff and evapotranspiration losses that operate on the undisturbed ground.

The close agreement between measured volumes of leachate from the 15 foot and 20 foot collectors on the C-b Tract suggest that the volumes measured in these two collectors are the most reliable volume data collected in the study to date.

Electrical Conductivity and pH - Electrical conductivity (EC) and pH were measured in the field at the time each sample was collected.

These data for the C.B. collection system are shown in Figure 8.11.2-3. Data for the 20 foot collector are very nearly the same as those shown and were omitted in the interest of clarity. The EC values average about 7,000 mhos/cm and increase only slightly with depth.

Quality of Leachate - Throughout the course of 1981, samples from the teflon bottles (designated A, B and C) were collected and many of them were prepared for chemical analysis. Analyses of waters contained in bottles B and C did not often differ significantly from those of bottle A water. Presentation and discussion of data from bottle A only is contained in this report. The chemical analyses reported herein represent approximately 70 percent of the total number of such analyses performed on leachate samples.

Table 8.11.2-2 contains data on the major ion composition of leachates collected at C.B. The concentration of dissolved solids in C-b leachate averaged from 6,450 to 7,050 mg/l. The composition of the leachates is dominated by sodium and sulfate. It appears that the calcium concentration is controlled by the solubility of calcium sulfate.

The concentration of nitrates in the leachate is greater than was anticipated. One obvious source for nitrates is residual from

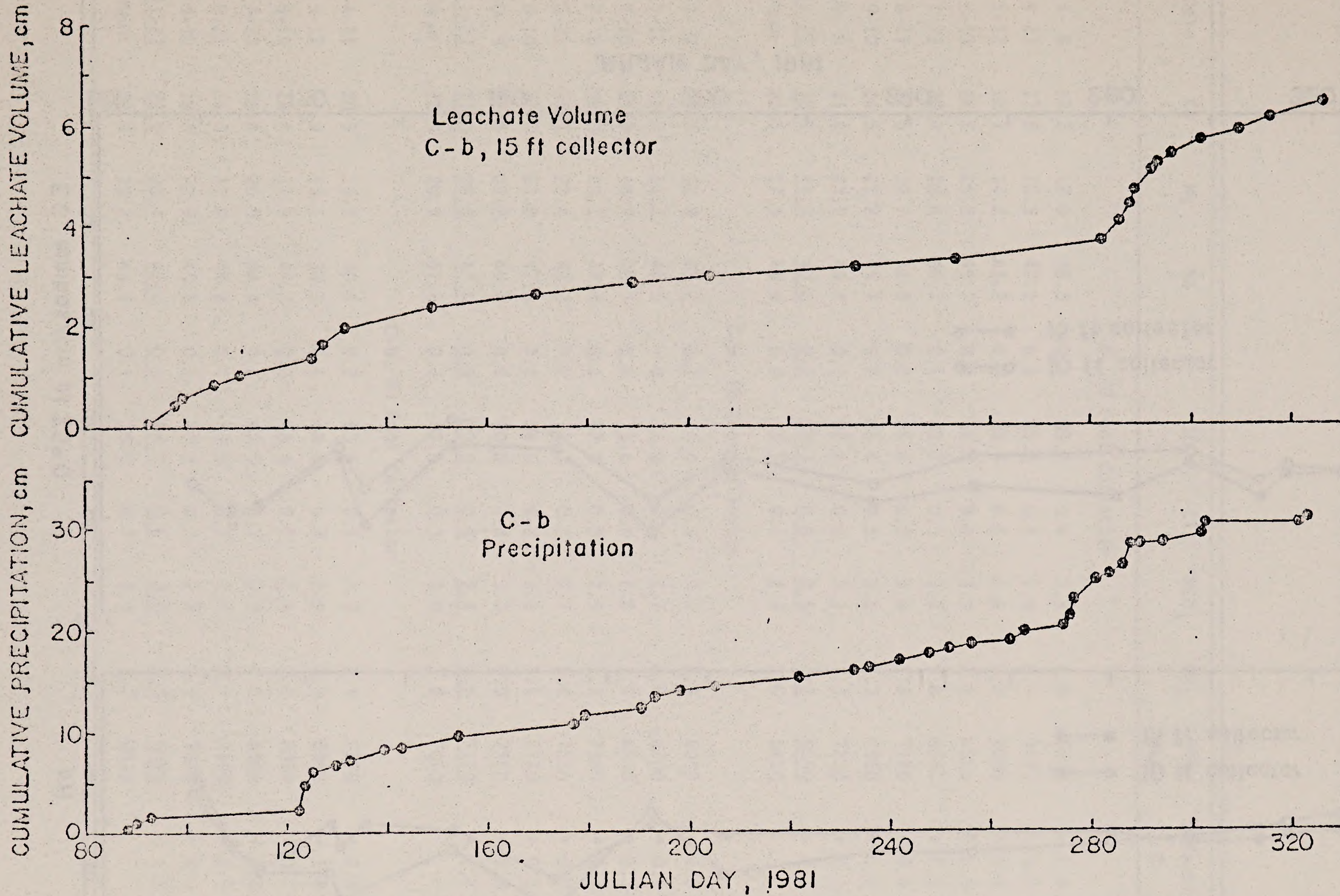


FIGURE 8.11.2-2 VOLUMES OF LEACHATE AND PRECIPITATION AT C.B.

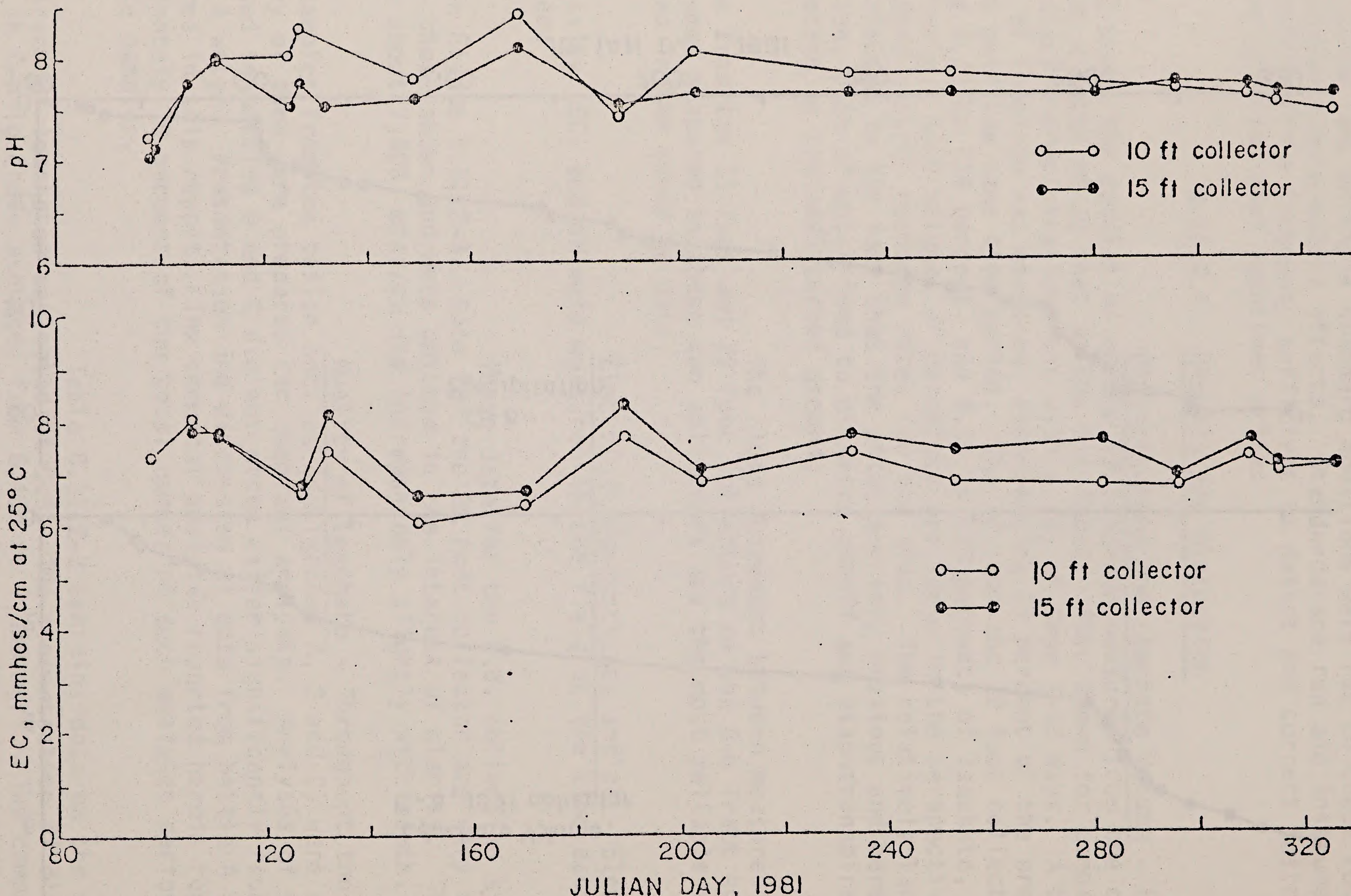


FIGURE 8.11.2-3 ELECTRICAL CONDUCTIVITY AND pH FOR C.B. COLLECTORS

TABLE 8.11.2-2 MAJOR ION COMPOSITION OF C.B. LEACHATE, 1981

Date	Ca	Mg	Na	K	SO_4	Cl	HCO_3	NO_3	TDS mg/ℓ	Balance %
				C-b, 10 Foot Collector						
4- 8	12.2	12.8	48.3	0.2	69.2	0.4	3.3	4.9	5950	- 1.8
4-21	17.8	10.9	42.1	0.2	65.6	0.4	2.9	3.5	5140	- 0.2
5-12	18.1	14.2	45.2	0.2	63.5	0.5	2.6	3.9	5690	+ 5.6
6-19	26.8	15.2	45.7	0.1	65.8	0.3	2.9	2.2	6120	-11.0
7-23	30.4	18.6	45.7	0.1	83.7	0.3	3.0	1.8	6930	+ 3.6
8-21	22.5	19.7	46.5	0.2	86.4	0.3	3.0	1.6	7120	- 0.8
9-10	24.5	21.2	45.7	0.2	85.4	0.3	3.1	1.3	7260	+ 1.2
10- 9	31.4	23.2	44.4	0.1	82.0	0.3	3.2	1.3	7230	+ 7.1
11-23	18.5	24.9	45.2	0.2	88.7	0.5	2.5	2.2	6590	- 2.2
Mean	22.5	17.9	45.4	0.2	76.7	0.4	2.9	2.5	6450	
				C-b, 15 Foot Collector						
4- 8	17.5	12.8	49.2	0.1	74.4	0.4	3.4	2.6	6030	- 0.5
5-12	19.0	16.2	46.5	~0	75.8	0.4	2.7	2.8	6200	+ 0.4
6-19	21.7	18.7	48.7	0.1	71.6	0.4	2.8	1.9	6830	+ 8.3
7- 8	26.0	20.1	47.4	0.1	87.9	0.3	2.5	1.7	7260	+ 1.1
8-21	26.5	22.4	48.3	0.2	93.3	0.3	2.7	1.4	7650	+ 0.2
9-10	27.0	23.8	47.8	0.2	94.5	0.3	3.1	1.1	7740	+ 0.3
10- 9	24.4	25.2	45.2	0.1	80.8	0.5	3.3	0.9	7560	+ 5.8
11-23	21.0	28.0	47.4	0.2	89.8	0.5	2.4	2.0	7120	+ 1.4
Mean	22.9	20.9	47.6	0.1	83.5	0.3	2.9	1.8	7050	
				C-b, 20 Foot Collector						
4-21	20.5	15.2	40.6	0.2	65.5	0.5	2.3	2.9	5580	+ 2.8
5-12	17.9	15.1	38.5	0.1	68.6	0.7	2.4	3.3	5590	- 1.8
6-19	28.4	17.9	44.4	0.2	68.4	0.7	2.4	2.7	6360	+10.7
7-23	26.4	20.5	44.4	0.1	83.5	0.7	2.3	2.5	6980	+ 1.6
8-21	26.0	21.8	45.7	0.1	83.5	0.7	2.4	2.1	7160	+ 2.9
9-10	18.5	22.9	45.2	0.1	80.8	0.7	2.5	2.1	7310	+ 0.6
11-23	22.0	20.7	45.7	0.3	86.2	0.6	2.0	3.3	6580	- 1.5
Mean	22.8	19.2	43.5	0.1	76.6	0.7	2.3	2.7	6510	

the explosives used in mining the shale. If this is indeed the major source, it is expected that a trend toward lower nitrate concentrations should be observed as a result of washing the residual explosive from the particle surfaces. Throughput volumes to date are too small to expect observation of a decreasing trend at this time.

Table 8.11.2-3 presents a summary of selected trace element concentrations observed in the leachate. Analyses for several other trace elements were performed, but those shown in the table are most significant. Fluoride concentrations in the leachate ranged from 5.1 to 10.5 mg/l the data do not show any trend with depth of collector. The concentrations of fluoride observed in the field generated leachates are similar to those measured in a previous column-leaching study, although the raw shales in the column were not the same as those that overly the collectors.

Concentrations of zinc and boron are significantly less than the maximum values observed for these elements in the previous column leaching tests. Again, the difference results from differences in materials used in the two studies. Molybdenum concentrations ranged as high as 11.3 mg/l and show a significant decreasing trend with time. The data suggest a decreasing trend with time of the concentrations of Ni and Al, but more data are required to firmly establish the trend.

Laboratory Leaching Tests - As mentioned previously, the column leaching tests of the raw shales overlying the field collectors are not yet complete. The ASTM water shake extraction tests for these materials are complete and data therefrom are compared with field data in this section. Table 8.11.2-4 contains the chemical analysis for the filtrate from the water shake extraction test.

The large water-to-shale ratio and the vigorous agitation used in the water shake tests make it reasonable to expect that the dissolved solids concentration in the filtrate is indicative of the total soluble salt content of the shales. A dry weight of 700 g of each shale was agitated in 2.8 liters of distilled water. The concentrations of total dissolved solids given in Table 8.11.2-4 are readily converted to soluble salt contents on a weight basis. The soluble salt content of the shale is 2.8 g/kg.

It is of some interest to investigate the degree to which the TDS concentration in the shake test filtrate can be used to predict the TDS concentration in field generated leachate. The simplest method for accomplishing this is based upon the highly questionable premise that the total weight of dissolved solids is independent of the volume of water in which they are dissolved. Data in the above paragraph and chemical principles suggest that this is a false premise. Nevertheless, if such a calculation would provide even roughly correct estimates of TDS, it would be useful. The in-place dry bulk density of the shales overlying the collectors is estimated at 1.4 g/cm^3. The porosity is also estimated to be 0.45. When the pores are saturated, the corresponding water-to-shale ratio is 0.32. Thus, the TDS concentration in the filtrate from the 4:1 water-to-shale shake test can be converted to the corresponding value with a 0.32:1 ratio by multiplying by 4/0.32 = 12.5. This yields 8875 mg/l as compared to an average of 6450 mg/l

TABLE 8.11.2-3 SELECTED TRACE ELEMENTS IN C.B. LEACHATE, 1981

Date	F	Zn	B	Si	Mo	Mn	Ni	Al	Sr
					mg/ℓ				
				C-b, 10 Foot Collector					
4- 8	8.7	0.052	0.626	4.9	11.3	0.140	0.33	2.5	11.3
4-21	6.9	0.155	0.494	4.2	6.9	0.117	0.23	1.6	8.6
5-12	6.4	0.455	0.269	3.2	5.2	0.100	0.31	2.8	12.0
6-19	6.4	0.154	0.394	4.5	2.5	0.150	0.31	2.5	11.0
8-21	10.5	0.173	0.650	5.9	1.6	0.200	0.13	<0.02	7.2
9-10	10.4	0.188	0.650	5.7	1.2	0.180	0.14	<0.02	6.9
10- 9	6.1	0.194	0.690	5.9	0.49	0.150	0.10	<0.02	6.9
11-23	6.6	0.127	0.478	3.7	2.21	0.081	0.071	1.21	8.1
				C-b, 15 Foot Collector					
4- 8	9.6	0.189	0.456	4.0	6.9	0.133	<0.05	1.1	6.9
5-12	6.5	0.155	0.299	3.0	3.4	0.103	<0.05	1.9	8.7
6-19	6.9	0.306	0.486	4.8	3.3	0.180	0.36	3.0	15.0
7- 8	10.5	0.239	0.550	4.6	1.8	0.230	0.18	<0.02	10.0
8-21	10.3	0.280	0.580	4.8	1.0	0.210	0.19	<0.02	9.2
9-10	10.2	0.319	0.600	5.1	0.6	0.180	0.19	<0.02	7.7
10- 9	6.4	0.373	0.590	5.0	0.7	0.140	0.16	<0.02	7.0
11-23	6.4	0.172	0.479	3.6	1.9	0.077	0.08	0.88	7.1
				C-b, 20 Foot Collector					
4-21	5.9	0.095	0.434	3.8	3.6	0.120	0.25	0.8	11.0
5-12	5.8	0.367	0.288	2.7	3.2	0.078	0.50	1.2	9.6
6-19	6.2	0.166	0.410	4.7	2.5	0.160	0.33	1.2	14.0
7-23	9.9	0.184	0.420	3.2	0.9	0.160	0.16	<0.02	8.8
8-21	9.8	0.203	0.440	3.5	0.6	0.160	0.16	<0.02	8.4
9-10	9.6	0.206	0.440	3.5	<0.05	0.140	0.15	<0.02	9.1
10- 9	5.1	0.050	0.240	3.9	<0.05	0.053	0.06	<0.02	3.6
11-23	5.6	0.076	0.372	3.4	1.61	0.035	0.07	0.70	8.6

TABLE 8.11.2-4 CHEMICAL ANALYSIS OF WATER SHAKE EXTRACTION TEST

Parameter		C-b* Raw
pH	----	8.57
EC	umhos/cm	850
ALK	mg/l	119.2
H_2CO_3	mg/l	0.85
HCO_3	mg/l	140.9
CO_3	mg/l	2.24
TDS	mg/l	710
F	mg/l	2.39
Cl	mg/l	2.75
PO_4	mg/l	<0.03
NO_3	mg/l	11.9
SO_4	mg/l	315
Zn	mg/l	0.008
Fe	mg/l	<0.005
Co	mg/l	<0.005
Li	mg/l	0.083
V	mg/l	<0.001
NH_3	mg/l	0.292
B	mg/l	0.120
Cd	mg/l	<0.001
Be	mg/l	0.0009
Mg	mg/l	38
P	mg/l	<0.05
Si	mg/l	1.9
Mo	mg/l	0.58
Mn	mg/l	0.010
Ni	mg/l	0.006
Na	mg/l	76
Cu	mg/l	0.003
Al	mg/l	0.23
Ca	mg/l	50
Ba	mg/l	0.142
K	mg/l	14
Cr	mg/l	0.007
Sr	mg/l	1.9
Pb	mg/l	0.011
Ag	mg/l	<0.001
Tl	mg/l	<0.005
Se	mg/l	<0.020
As	mg/l	<0.010
Hg	mg/l	<0.001
Total N	mg/l	1.94

*Raw shale overlying 10 ft collector at C-b Tract

measured from the 10 foot collector. This is a reasonable agreement considering that the bulk density and porosity of the raw shale piles in the field are only estimated values.

The above indicated agreement between measured and calculated values of TDS concentration is believed to be largely fortuitous, however. The chemical composition of the filtrate from the shaker tests bears little resemblance to that of the field generated leachates as shown in Table 8.11.2-5. The disparity in the compositions of the filtrates and the field leachates is not surprising. The concentrations of one or more of the constituents in the field leachate may be solubility controlled. The much greater water-to-shale ratio in the shaker tests is expected to remove this constraint on concentration.

Similar considerations are expected to apply for the trace elements. Table 8.11.2-6 compares the concentrations of selected trace species in the shaker filtrate with field values. The shaker values have been multiplied by 12.5 to convert them to approximately the water-to-shale ratio believed to represent field conditions. Again, there is little or no quantitative correspondence between the measured and calculated concentrations.

8.11.2.5 Summary and Conclusions

Two sets of leachate collectors were constructed as integral parts of raw mined shale storage piles during the Summer and Fall, 1980. The purpose of the collectors was to provide samples of leachage from which the quality and quantity of percolating waters could be documented.

Three collectors were placed at depths of 10 feet, 15 feet, and 20 feet. Leachate intercepted by the collectors is routed to collection vessels. Records of cumulative volume of leachate produced by each collector are prepared and samples are taken for chemical analysis. Nearby precipitation gauges provide records of precipitation.

The cumulative volume of leachate collected is 4.36 to 6.39 cm^3/cm^2. The leachate volumes collected are believed to be representative of ambient percolate volumes in the shale. The leachate volume of 6.39 cm^3/cm^2 measured in the 10 foot collector represents 21 percent of the incident precipitation.

The pH of the leachate averaged about 7.7 during 1981. The EC and TDS of the C.B. leachate averaged about 7,000 umhos/cm and 6,700 mg/l, respectively. The leachate tends toward a sodium-sulfate water with these two species representing 72.4 percent of the total equivalent weight of dissolved species. Trace element concentrations are generally low in the leachates.

TABLE 8.11.2-5

COMPARISON OF COMPOSITION OF SHAKER TEST FILTRATE WITH FIELD LEACHATES

Constituent	Percent of Total Milliequivalents — C-b Raw Shale: Shaker	Percent of Total Milliequivalents — C-b Raw Shale: Field
Ca	13.1	13.3
Mg	16.4	10.6
Na	17.4	26.9
K	1.9	0.1
SO_4	34.4	45.5
HCO_3	12.1	1.7
Cl	0.4	0.2
NO_3	1.0	1.5

TABLE 8.11.2-6

TRACE ELEMENT CONCENTRATIONS IN SHAKER FILTRATE COMPARED WITH FIELD LEACHATE VALUES

Element	Concentration, mg/l C-b Shaker	Field
F	29.9	7.8
Zn	0.100	0.187
B	1.50	0.531
Si	23.8	4.8
Mo	7.2	3.9
Mn	0.13	0.14
Ni	0.08	0.20
Al	2.9	<1.3
Sr	23.8	9.0

Water extraction shake test (a proposed ASTM test) was performed on samples of the raw shale overlying the collectors. The TDS concentrations in filtrates from these tests were used to calculate soluble salt content per unit weight of shale. The ASTM recommended ratio of water-to-shale resulted in 2.8 g/kg. A water-to-shale ratio 5 times larger than the recommended ratio produced soluble salt content as much as 39 percent greater than obtained by the recommended test. Conversion of shake test TDS values to a water-to-shale ratio corresponding to a saturated pore volume gave results in surprisingly close agreement with field measured values. However, the composition of the shaker test filtrate bore little resemblance to that of the field generated leachate in accordance with expectations.

8.11.3 Excess Mine Water Disposal - Land Application System Impacts

8.11.3.1 Scope

Excess mine water was disposed on approximately 100 acres using large sprinklers starting in mid-July and ending in mid-Ocotober in 1980 and 1981. Sprinkling is limited to spring, summer and fall months during the time when atmospheric and vegetative water demands are relatively high. During this period, water can be safely applied by sprinkling with a limited risk of disrupting the environmental balance.

The principal mechanisms of water disposal to the air are evaporation, from the time water leaves the nozzle until the soil and plant surfaces are dry, and transpiration when the leaf stomata are open. Evaporation and transpiration should balance (consume) the amount of water applied to the soil by precipitation and sprinkling to limit water percolating below the root zone. This limits leaching of salts from the soil thus preserving groundwater quantity and quality.

Salt in the applied water is concentrated in the soil by evapotranspiration when leaching is avoided. Plants will benefit from the irrigation as long as the salinity of the soil and specific ion concentrations do not reach toxic levels.

Potential hazards associated with salts in the irrigation water when applied by sprinkler are their accumulation in and on vegetation. Harmful levels of specific ions in the foliage can affect the plant and animals that consume large quantities of the vegetation. Some plants are sensitive to sodium and boron while flouride can harm animals.

8.11.3.2 Objective

The purpose of this study is to monitor the environment and to control the irrigation application such that the maximum amount of excess mine water can be safely disposed via the evapotranspiration processes without significant deep percolation.

Efforts are being made to manage the system so that deep percolation is limited, toxic soil salt levels are avoided, and salts accumulated on or in the plant foliage will not damage plants or the animals that consume it. Using the results of the study to date, recommendations are made for operating the system in the future and for continuing the monitoring program.

8.11.3.3 Experimental Design

Treatments designed for the study are presented in Table 8.11.3-1. Figure A8.11.3-1 shows a sketch of the irrigation system layout including the locations of the sample (treatment) sites.

Water Distribution System - Water was pumped from Pond C to and through the mainline which is buried on the ridge top. Sprinkler laterals were placed at approximately right angles to the main (see Figure A8.11.3-1). Quick-coupled big-gun sprinklers were attached to risers on stands along the laterals. The system was designed to deliver 220 gallons per minute (gpm) to each of two operating sprinklers for a total of 440 gpm. Rainbird Model 105CS sprinklers with 0.89 inch straight bore nozzles discharged the water over a circular area having a wetted radius of approximately 160 feet. The average application rate, using the flow rate and wetted area, was 0.67 centimeters per hour (cm/hr) or 8.0 cm per 12 hours. The standard operating time was 12 hours per set except in the study area. Various application amounts were applied in the intensively monitored study areas. The different amounts were achieved by using application times of 6, 12, and 18 hours, giving 4.0 cm, 8.0 cm and 12.0 cm application amounts (Table 8.11.3-1).

8.11.3.4 Method of Analysis

Soil Water - Deep percolation was estimated from a water budget which accounted for excesses in application over evapotranspiration, ET. Estimates of ET were computed from meteorological data which were available at the site. The actual amount of drainage (deep percolation) below the root zone can also be inferred from changes in soil moisture as a function of time and depth at a given point.

Water content was initially measured by the gravimetric technique (mass bases) and later by using a Campbell Pacific hydroprobe neutron moisture meter (see data in Tables A8.11.3-1a and A8.11.3-1b). An Oakfield soil sampler was used to extract samples for measuring soil moisture on a mass (weight) basis. To convert from a mass to a volume basis, which was necessary for comparison with the hydroprobe readings, the average bulk soil density of 1.1 grams per centimeter cubed (g/cm^3) was determined and used. Thus, the gravimetric and estimated volumetric water contents were nearly the same.

TABLE 8.11.3-1

Treatments and Items Measured During the Impact Study of Excess Mine Water Disposal by Irrigation During the 1980 and 1981 Seasons

Treatment	Set Time Hours	Set Period 1/	Irrigation Interval Days 2/	Number of Samples and Items Monitored 3/
4a 4/	18	Random	15	10P 5/, 7W
4b	12	Random	15	10P, 4W
5a	18	Random	15	10P, 4S, 5W
5b	12	Random	15	10P, 5B, 5F, 4S, 10W, 5Na
5c	6	Random	15	4S, 4W
6b	12	Day	15	5B, 5F, 5Na
7c	6	Day	7 6/	5B, 5F, 4S, 4W, 5Na
8b	12	Night	15	5B, 5F, 5Na
Control (C)	--	--	--	4W, 4S

1/ Period of time when irrigated

2/ Actual intervals used varied considerably (see irrigation data in Table 8.11.3-2)

3/ Letters represent the following:

P - Herbaceous productivity	B - Plant boron
S - Soil sample	F - Plant fluoride
W - Soil water	Na - Plant sodium

4/ Treatments 4a and 4b received application of 200 lbs N and 100 lbs P per acre

5/ Herbaceous productivity determined by Cathedral Bluffs Shale Oil Company

6/ Two irrigations per 15 day interval

The hydroprobe was used throughout the 1981 season. Access tubes for the neutron probe were installed to the fall soil depth in the various treatment areas to provide a convenient means for measuring soil moisture before and after each irrigation. Additional deep probe holes were installed in treatments 4b and 5b between the 1980 and 1981 seasons. If the volumetric soil moisture at the lower depths is above field capacity (approximately 32%) after an irrigation, it can be assumed that there is deep percolation and the depth of irrigation should be reduced or the interval between irrigations increased. The neutron probe will facilitate rapid and accurate moisture readings for irrigation management in future seasons.

Irrigations in 1981 were scheduled to follow a consumptive water use curve and the curve used in 1981 was refined using data collected in 1981.

Soil Water Quality - Excess mine water was sampled periodically and analyzed. Salinity, boron, fluoride, and total dissolved solids (TDS) are presented in Tables A8.11.3-2a and A8.11.3-2b for 1980 and 1981, respectively.

Soil salt movement and accumulation were estimated from pH, electrical conductivity of saturation extracts (ECe), exchangeable sodium percentage (ESP), and boron concentration (see data in Table A8.11.3-3). Samples were taken within 5 feet of the access tubes with the aid of an engine-powered soil auger, except on December 6, 1980, when an Oakfield soil auger was used to extract the soil samples at the same locations.

Foliar Salt Uptake - Indian ricegrass (Oryzopsis hymenoides), western wheatgrass (Agropyron smithii), and big sagebrush (Artemesia tridentata wyomingenses or Artemesia tridentata tridentata) were tagged and in each case new growth was sampled (see data in Tables A8.11.3-4a, A8.11.3-4b, A8.11.3-4c, A8.11.3-5a, A8.11.3-5b, A8.11.3-5c, A8.11.3-6a, A8.11.3-6b, and A8.11.3-6c). Samples were taken on June 5 and December 16, 1980 and after each irrigation cycle during 1981 from the same plants or an adjacent area. In treatment areas where both soil moisture and foliage were sampled, the plant samples were taken from plants near the neutron meter access tubes.

8.11.3.5 Results and Discussion

Deep Percolation and Lateral Seepage - Water budgeting was used to estimate deep percolation by accounting for daily consumptive use, precipitation and the available soil water storage for use by the plants. The process is begun by assuming no available stored water. Following the first and subsequent irrigations, water is consumed at a rate proportional to atmospheric water demand. The estimated depth of water used each day is subtracted from the stored water. Irrigation and precipitation replace the depleted water. When more water was added than the soil could store, deep percolation was assumed.

Estimates of daily consumptive water use or evapotranspiration (ET) and available water storage are used in the water

budgeting process. The Hargreaves (1977) equation was used to estimate potential daily evapotranspiration, ETP, during 1980 and the Jensen-Haise (1964) equation, modified for the Piceance Basin was used during 1981. Weather data for both years is presented in Tables A8.11.3-7a and A8.11.3-7b. A 5 percent loss from drift and direct evaporation from spray were assumed (EFF = 95%). The weighted average crop cover, C = 0.70, was estimated by assuming an average irrigation interval of 21 days with full ET for the first 2 days following each irrigation and an average crop cover (density) of two thirds. Crop canopy architecture was assumed to be similar to alfalfa and K = 1.2 was used as the crop coefficient to give the following equation for predicting daily ET:

$$ET = \frac{C\ K}{EFF/100}\ ET_p$$

$$ET_{(1980)} = \frac{0.70x1.2}{0.95}\ [0.0075\ (1.8\ T + 32)\ RS]/(597.0 - 0.6\ T)$$

$$ET_{(1981)} = \frac{0.70x1.2}{0.95}\ [0.0232\ (T)\ RS + 0.2210\ RS]/(597.0 - 0.6\ T)$$

where:

ET is consumptive use or evapotranspiration in cm/day
ET_p is the potential evapotranspiration in cm/day
C is the weighted average crop cover
K is the crop coefficient
T is average daily temperature in °C
RS is the solar radiation in Langleys/day.

Radiation and temperature data were recorded at the C-b Tract. The radiation measurements taken in 1980 appeared to be in error when compared to published average figures for Grand Junction and past years' measurements at C-b Tract. Therefore, the C-b Tract radiometer data were not used and the Grand Junction data were used to approximate RS in 1980. This appears to be a reasonable procedure in view of the proximity of the two locations and surrounding topography. Measurements taken at C-b were used in 1981. The following relationship developed by Hargreaves (1981) was used to estimate the radiation at the C-b Tract:

$$RS = b\ [RA \times (\Delta T)^{1/2}]$$

where:

b is a coefficient which varies with location
RA is the extraterrestrial radiation in Langleys/day
T is the difference between the maximum and minimum daily temperature in °F.

The average July 1980 values of RS = 633 Langleys/day at Grand Junction, Table A8.11.3-8; RA = 1000 calculated from Christiansen (1968); and the average daily ΔT = 21.7 °F during July 1980 at the C-b Tract were used to compute b = 0.136.

Available water storage capacity was calculated from neutron probe readings taken October 17, 1980 and during 1981 (see Tables A8.11.3-1a and A8.11.3-1b). The unirrigated control treatment values were used to calculate the lower limit of available water (12.5%) and treatment 5a was selected for the upper limit (32%) since it was the last to be irrigated. The difference between these values was then multiplied by an average soil depth of 61 cm to arrive at 12 cm of available water storage for use by the plants. This is assumed to be the maximum depth of water which can be safely applied and stored without causing deep percolation.

Estimated quantities of deep percolation calculated by the water budget method for 1980 and 1981 are presented in Tables 8.11.3-2a and 8.11.3-2b. The 1980 application times ranged from 6 to 18 hours giving 4 to 12 cm of average application per irrigation. Under the given irrigation frequency for treatment 5a, with 12 cm application, it was estimated that 19.0 cm or one-third the water applied went to deep percolation. For treatment 5b with 8 cm application during 1980, it was estimated that deep percolation was 1.3 cm. With the lighter irrigations (4.0 cm) but similar intervals between irrigations, treatment 5c produced no deep percolation. For treatment 7c with 4.0 cm, with applications twice as often, there was no calculated deep percolation according to the water budget analysis.

The consumptive use curve shown in Figure 8.11.3-1 was used to improve irrigation scheduling during the 1981 season (Keller et al. (1980). Improvement is seen in treatment 5b where calculated deep percolation was zero, compared with 1.3 cm during 1980, while the average available soil moisture after irrigation remained near 9.4 cm. Estimated deep percolation in treatment 5a was also decreased to about one-sixth of total depth of applied water. As was the case in 1980, treatment 5c, with less frequent lighter irrigations, and 7c, with more frequent, lighter irrigations produced no deep percolation.

Soil moisture results presented in Table 8.11.3-1b for the 1981 season aid in interpreting water budget findings. Water content measurements from the deep holes installed in association with treatments 4a and 5a are particularly useful in making a case for limited deep percolation, 6.64 cm, in treatment 5a, during 1981. Treatment 4a had the same irrigation strategy as 5a with 18.0 cm of water applied, but fertilizer was applied in addition to water. Stable low-water-content profiles below 60 inches could be used to suggest little water is transported or stored below that depth. Soils below 60 inches in these treatments probably have the capacity to retain more water than is reported. With a greater soil volume to store water, the 6.64 cm deep percolation calculated for treatment 5a was likely retained and thus deep percolation was minimized. Lighter irrigation, 4.0 cm, resulted in lower water content after irrigation in treatments 5c and 7c. The soil profile was filled to near field capacity in treatments 4b and 5b.

The importance of irrigation scheduling is exemplified by the difference in losses between treatments 5a, 5b, 5c, and 7c. Generally, as the amount of applied water per irrigation increases, the interval between irrigations should also be increased for a given soil water holding capacity. Even with the 18 hour set, giving 12 cm of applied water, deep percolation could be controlled if sufficient time were allowed between

TABLE 8.11.3-2a

Estimates of deep percolation during 1980 based on the water budget method.

Treatment	Irrigation Date	Depth of Water Applied (cm)	Available Soil Water After Irrigation (cm)	Consumptive[1/] Use Between Irrigations (cm)	Estimated Deep Percolation (cm)
5a	7-24	12.0	12.0		0.00
	8-9	12.0	12.00	8.00	4.00
	8-29	12.0	12.00	7.88	4.12
	9-23	12.0	12.00	7.77	4.23
	10-13	12.0	12.00	5.38	6.61
Totals		60.0		29.03	18.97
5b	7-27	8.0	8.00		0.00
	8-13	8.0	8.00	8.40	0.00
	8-22	8.0	12.00	3.55	0.45
	9-24	8.0	9.00	10.40	0.00
	10-11	8.0	12.00	4.76	0.84
Totals		40.0		27.11	1.29
5c	7-24	4.0	4.0		0.0
	8-13	4.0	4.0	9.97	0.0
	9-24	4.0	4.0	13.95	0.0
	10-11	4.0	4.0	4.76	0.0
Totals		16.0		28.68	
7c	7-14	4.0	4.00		0.00
	7-24	4.0	4.00	5.17	0.00
	8-1	4.0	4.00	4.07	0.00
	8-8	4.0	4.52	3.48	0.00
	8-19	4.0	4.00	4.70	0.00
	8-28	4.0	4.65	3.35	0.00
	9-8	4.0	4.94	3.71	0.00
	9-22	4.0	4.87	4.07	0.00
	10-9	4.0	4.06	4.81	0.00
Totals		36.0		33.36	0.00

[1/] Calculation based on Hargreaves consumptive use equation with estimated radiation.

TABLE 8.11.3-2b

Estimates of deep percolation during 1981 using the water budget method.

Treatment	Irrigation Date	Depth of Water Applied (cm)	Available Soil Water After Irrigation (cm)	Consumptive[1/] Use Between Irrigations (cm)	Estimated Deep Percolation (cm)
5a	6-26	4.0	4.0		0.00
	7-19	12.0	12.0	5.60	0.00
	8-4	12.0	12.0	6.85	5.15
	8-21	8.0	12.0	6.51	1.49
Total		36.0		18.96	6.64
5b	6-26	8.0	8.0		0.00
	7-16	8.0	10.7	5.32	0.00
	8-4	8.0	11.0	7.66	0.00
	8-19	3.3	8.5	5.85	0.00
Total		27.3		18.83	0.00
5c	6-16	2.0	2.0		0.00
	6-25	4.0	4.0	5.81	0.00
	7-16	4.0	4.0	5.46	0.00
	8-3	4.0	4.0	6.96	0.00
	8-19	4.0	4.0	6.55	0.00
	9-24	4.0	4.0	8.31	0.00
Total		22.0		33.09	0.00
7c	6-8	3.3	3.3		0.00
	6-15	4.0	4.0	3.97	0.00
	7-6	4.0	4.0	8.87	0.00
	7-15	4.0	5.2	2.79	0.00
	7-22	4.0	5.9	3.27	0.00
	8-2	4.0	6.0	3.90	0.00
	8-8	4.0	6.7	3.30	0.00
	8-18	4.0	7.9	2.79	0.00
	8-25	4.0	10.0	1.92	0.00
	9-23	8.0	10.5	7.49	0.00
Total		43.3		38.30	

1/ Calculation based on Jensen-Haize equation modified for Piceance Basin.

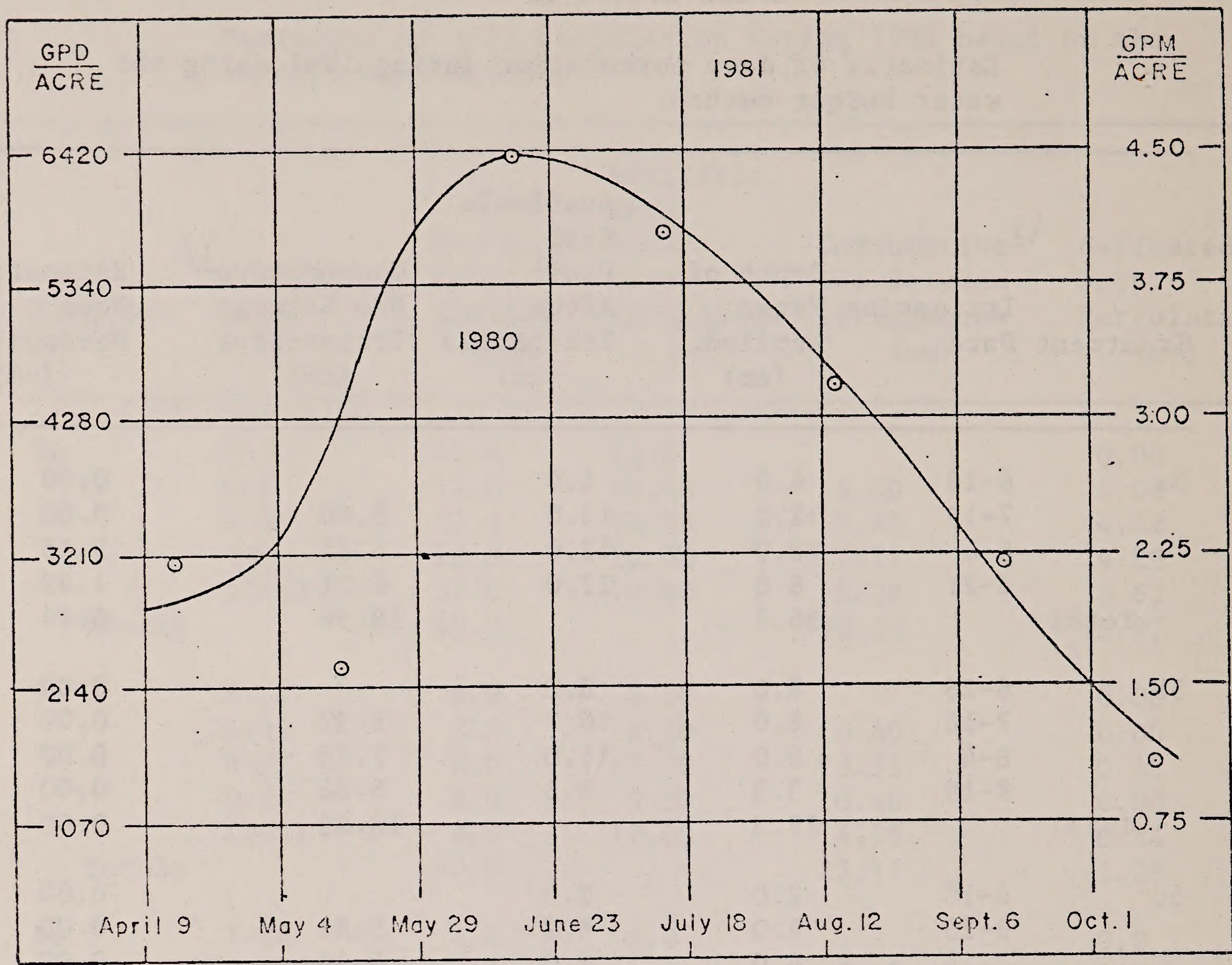


Figure 8.11.3-1 Simulated gross consumptive use curve at C-b Tract. Gallons per day per acre (gpd/acre) (assuming 24 hour operation) or gallons per minute per acre (gpm/acre) based on Jensen Haize (1963) equation using 1981 monthly temperature and radiation.

irrigations; but all the available water would have to be consumed between irrigations to avoid deep percolation. Availability of soil water is enhanced by irrigating more frequently and applying less than the maximum soil water holding capacity of 12 cm. With frequent irrigations, giving a favorable soil water status near field capacity, ET will remain near the peak, depending only on the atmospheric demand. However, the practical irrigation frequency is limited by labor and scheduling considerations.

Lateral seepage outside the sprinkled areas was estimated by observing changes in the soil moisture content down slope from the irrigated area at the L6 and L21 seepage test sites indicated on Figure A8.11.3-1. The L6 and L21 data presented in Tables A8.11.3-1a and A8.11.3-1b show little change in moisture content with time. This indicates that there was probably little lateral seepage from the sprinkled area.

Salt transport and accumulation are important in monitoring water percolating out of the root zone. Checking the salt balance is one method for estimating whether deep percolation has occurred in an area sprinkled with a known quality and quantity of water. The ECe would increase in proportion to the mass of salt added with the irrigation water during the season, assuming dissolution and/or precipitation does not occur. Leaching (especially in the top foot of soil) and precipitation effects are confounded in this analysis, thus an estimate of deep percolation based on a salt balance analysis is not meaningful.

Irrigation Scheduling - The frequency of irrigation and depth of water stored during each irrigation are closely related. Short set times giving lighter amounts of applied water require frequent irrigations. A convenient set time is 12 hours with 2 sprinkler moves per day. With 12 hour sets, 8 cm of water are applied per application. A depletion of 8 cm is 75% of the 12 cm of available moisture in a 61 cm (2-foot) root zone. This schedule minimizes the labor input while maintaining relatively high consumptive use rate without causing excessive deep percolation.

Figure 8.11.3-1 gives estimates of the rate at which water could be safely disposed (evapotranspired) on a per acre basis by native vegetation under irrigated conditions at the C-b Tract sprinkler site during the 1981 season. The scheduling curve developed for 1980 was adjusted using the more reliable temperature and radiation data collected in 1981. Monthly averages of radiation and temperature coupled with temperature data from C-b Tract were used to develop the curve in Figure 8.11.3-1 (see Table A8.11.3-8). May 1981, was cloudier and cooler than April, and that caused the reverse slope in the curve. Calculated ET for 1981 was greater than estimated 1980 ET except during April and May. The gallons per minute figures represent the continuous (24-hr/day) gross flow rates per acre which would replenish the water consumed through ET. For example, to dispose of 440 gpm in June and July would require sprinkling approximately 100 acres, but in September the system would need to be expanded to cover 200 acres (440/2.2) in order to minimize deep percolation.

Pan Evaporation Estimation - Estimates of pan evaporation can be made using available weather data in the Hargreaves equation as mentioned earlier. Appropriate constants were found in "Crop Water

Requirements", published by FAO in 1975. Under climatic conditions similar to those at the C-b Tract, with strong winds, a pan surrounded by dry land, and a long fetch, the relationship between pan evaporation and consumptive use is:

$$E_{pan} = 2.07 \text{ ET}$$

where

E_{pan} is pan evaporation, cm/day

ET is consumptive use with 100% alfalfa crop cover, cm/day.

Soil Chemical Properties - Some salts from the applied mine water concentrate in the soil as the plants extract water and as it evaporated from the soil surface. These can be harmful to the plants if safe tolerance levels are exceeded. The exchangeable sodium percentage (ESP), pH, and boron concentration, which are presented in Table 8.11.3-3, were measured before and after sprinkling to monitor possible ion toxicity and nutrient availability. High exchangeable sodium can cause toxicity to plants as well as reduce the water infiltration capability of the soil which encourages runoff. Nutrient availability is strongly related to soil pH. Boron can cause plant damage even at low concentrations.

Criteria for soil nutrient availability and soil toxicity have been developed by researchers. Over the range of pH values measured in treatments 5a, 5b, 5c, and 7c, nutrients should be readily available to the plants according to Buckman and Brady (1969). Maas and Hoffman (1977) published criteria for ECe, ESP, and boron. ECe of less than or equal to 2.0 mmhos/cm may cause a slight yield reduction only in the more sensitive forage crops. Some forage crops, such as western wheatgrass, can tolerate ECe levels as high as 12 mmhos/cm with little loss in production. Treatments 5a and 5b have ESP's of ten or greater; consequently, injury from sodium could become a problem in future seasons if the trend continues.

Boron concentrations greater than or equal to 2.0 ppm can cause damage to sensitive crops. Boron concentrations in all treatments were less than the harmful (or toxic) levels as shown in Table 8.11.3-3. There does not appear to be a strong relationship between the amount of water applied or treatment and the soil chemical change. Soil fluoride from applied water is fixed near the soil surface; therefore, it is not available to plants for uptake.

Chemistry of the Foliage - The excess mine water applied to the vegetation during sprinkling deposits dissolved solids on the foliage. Foliar salt uptake data are presented in Table 8.11.3-4 for fluoride and Table 8.11.3-5 for boron and sodium, the three cations of primary concern. Plants are sensitive to sodium and boron and animals can be harmed by consuming large quantities of vegetation if fluoride concentrations are sufficiently high.

Fluoride - Fluoride toxicosis was reported by Shupe et al. (1978) when western wheatgrass containing 60 ppm was consumed by livestock. Table 8.11.3-6 taken from Shupe et.al. (1978) reviews fluoride tolerance levels in livestock drinking water and feed. Fluoride toxicosis in domestic and wild animals can be influenced by the following factors: (1)

TABLE 8.11.3-3

Average of pH, electrical conductivity of saturation extract (ECe), exchangeable sodium percentage (ESP), and boron on soil samples taken June 5 and December 16, 1980 and October 26, 1981.

		pH (-log[H])			ECe (mmhos/cm)			ESP (%)			Boron (ppm)		
		1980		1981	1980		1981	1980		1981	1980		1981
Treatment	Depth	June	Dec	Oct	June	Dec	Oct	June	Dec	Oct	June	Dec	Oct
5a	0-1	7.7 a*	8.4	8.7	1.0	1.1	1.9	<1 a	8.0	12.8	0.8	0.9	0.3
	1-2	--	--	8.5	0.7	--	1.4	<1	--	9.3	0.6	--	<.1
5b	0-1	7.8 a	8.3	8.7	0.9	0.8	1.2	<1 a	6.0	10.0	1.1	0.4	0.3
	1-2	7.8	--	8.4	0.7	--	0.9	<1	--	3.0	0.6	--	<.1
	2-2.5	8.1	--	8.4	0.7	--	0.9	<1	--	3.0	0.8	--	--
5c	0-1	7.3 a	8.2	8.5	0.4	1.0	0.8	<	5.8	6.8	0.3	0.8	0.5
	1-2	7.8	--	8.3	0.4	--	0.8	<	--	2.3	0.3	--	0.2
7c	0-1	7.9	8.4	8.7	0.6	0.6	1.0	1.8	7.8	6.5	0.7	0.6	0.8
	1-2	8.1	--	8.6	1.1	--	1.1	7.3	--	3.0	1.8	--	0.4
Control	0-1	--	--	7.9			0.8			1.8			<.1
	1-2			8.2			0.5			1.0			<.1

*Values having "a" between them differ at the 0.05 probability level by the T test.

TABLE 8.11.3-4

Average fluoride concentrations in foliage of Indian rice grass, western wheat grass and big sage brush on June 5 and December 16, 1980; on April 20, July 10, August 26, and October 26, 1981.

Vegetation Type	Treatment	Fluoride (ppm) 1980 June	1980 Dec.	1981 April	1981 July	1981 Aug.	1981 Oct.
Indian rice grass	5b	3.2	10.5	0.2	9.7	50.3	22.3
	6b	0.4	39.5	3.2	9.1	115.5	42.0
	7c	0.3	45.7	1.3	44.4	127.5	53.8
	8b	--	--	--	--	--	--
	c	--	--	0.3	--	--	17.0
Western wheat grass	5b	2.0	27.6	4.5	10.8	50.9	19.0
	6b	10.8	41.4	1.0	8.6	82.0	22.9
	7c	1.4	45.0	2.6	38.6	133.8	38.4
	8b	0.4	32.2	2.7	7.9	41.5	26.9
	c	--	--	1.6	--	--	23.8
Big sage brush	5b	0.2	8.8	5.8	19.9	122.9	13.2
	6b	3.0	16.4	12.2	11.7	131.1	24.3
	7c	0.4	18.0	8.9	128.1	187.7	26.9
	8b	0.0	8.6	4.5	8.6	55.7	16.7
	c	--	--	0.3	--	--	10.40

TABLE 8.11.3-5

Average boron and sodium concentrations in foliage of Indian rice grass, western wheat, and big sage brush on June 5 and December 16, 1980 and April 30 and October 1981.

Vegetation type	Treatment	Boron (ppm) 1980 June	Dec.	1981 April	Oct.
Indian Rice Grass	5b	92.1	29.7	10.1	2.1
	6b	33.4	86.1	25.7	2.1
	7c	81.5	41.4	17.7	2.1
	8b	—	—	—	—
	c	—	—	14.6	2.1
Western Wheat Grass	5b	60.1	32.3	12.2	2.5
	6b	22.8	47.9	33.3	2.1
	7c	41.9	29.4	23.3	5.5
	8b	71.4	41.4	9.0	2.7
	c	—	—	8.9	2.2
Big Sage Brush	5b	120.8	113.0	121.3	87.6
	6b	50.5	106.8	92.5	45.7
	7c	79.1	138.4	147.9	48.6
	8b	225.4	101.6	53.5	70.6
	c	—	—	108.9	21.6
		Sodium (ppm)			
Indian Rice Grass	5b	24.6	657.0	15.1	1628.3
	6b	13.8	595.8	16.8	2186.6
	7c	13.6	661.5	12.1	1784.7
	8b	—	—	—	—
	c	—	—	15.9	475.2
Western Wheat Grass	5b	34.2	455.1	14.8	354.4
	6b	94.9	517.5	12.3	365.4
	7c	45.1	713.3	14.2	626.3
	8b	37.7	444.1	15.4	390.8
	c	—	—	11.4	212.8
Big Sage Brush	5b	40.6	663.5	17.9	214.7
	6b	61.6	573.2	24.1	392.0
	7c	1867.0	1099.2	51.3	635.3
	8b	60.4	803.4	23.7	157.4
	c	—	—	12.8	57.9

TABLE 8.11.3-6

Fluoride tolerance[1/] levels in feed and water of domestic animals.

Species	Feed[2/] ppm	Water [3/] mg/liter
Heifers, dairy and beef cattle	30	2.5-5
Dairy cattle, mature	40	4-8
Beef cattle, mature	50	6-10
Finishing cattle	100	12-15
Breeding ewes	60	6-9
Horses	60	4-10
Feeder lambs	150	12-15

1/ Biological availability depends on chemical composition. Dissolved F in water appears to be more readily assimilated than other forms.

2/ The values must be reduced proportionately when both water and feed contain appreciable amounts of fluoride.

3/ The average ambient air temperature and the physical and biological activity of the animals influence the amount of water consumed and hence the wide range of tolerance levels suggested. For active animals in a warm climate the lower values should be used as critical indicators.

amount of fluoride ingested; (2) duration of fluoride ingestion (time); (3) fluctuation in fluoride intake with time (often seasonal); (4) solubility of fluoride--toxicity usually increases with solubility; (5) species of animals involved: (6) age of animal at time of fluoride ingestion; (7) general level of nutrition--malnutrition intensifies toxicity; (8) stress factors; and (9) individual biologic response. The tolerance levels presented in Table 8.11.3-6 can be increased under conditions of seasonal consumption and mixing with vegetation consumed in adjacent areas that does not contain fluoride.

Only treatments 6b and 7c have fluoride concentrations that approach the toxic tolerance levels during 1980 (see Table 8.11.3-4). The standard random 12-hour set-time project treatment is safe according to the tolerance levels suggested by Shupe et al. in Table 8.11.3-6. The daytime sprinkling apparently accelerated the fluoride accumulation because treatment 6b and 7c levels were higher in all three vegetation types than the other random and night-only treatments. However, big sagebrush accumulated less fluoride than the grasses in every treatment.

Fluoride concentration declined sharply during the off-season between 1980 and 1981 then increased with sprinkling in 1981 (see Table 8.11.3-4). Dilution from plant growth and leaching from winter rain probably contributed to the decrease in fluoride concentration between the 1980 and 1981 irrigation seasons. Differences between June 1980 and April 1981 levels could be explained by plant and sampling variability. The sharp peak in August is a deviation from the expected smooth increase in fluoride concentration with sprinkling time.

A leaf sample storage problem is likely the cause of the rapid increase. After sampling, the fresh leaves were stored in air tight plastic containers rather than paper bags which allow vapor to escape. The plant material was lost in transit during August and part of September and warm temperatures coupled with high humidity encourage decomposition. Decomposition reduced dry matter weight but fluoride mass was probably not affected. A reduction in dry matter, while holding the total fluoride constant, increases the fluoride concentration on a dry weight basis. A similar argument might explain the high fluoride concentration in treatment 7c July 10. Sprinkling and plant material effects are consistent with 1980 trends if the high fluoride concentrations mentioned are omitted. The fluoride levels at the end of 1980 and 1981 should not cause problems for animals feeding on the vegetation.

Sodium and Boron - Criteria for sodium and boron in vegetation are focused on plant toxicity. According to Ehlig and Bernstein (1959) toxic foliar concentrations range from about 10 to 30 meq NaCl per 100 grams dry weight for apricot and almond trees (which are very sensitive to Na and Cl and the rate of accumulation) did not seem to alter the toxicity level. The converted toxicity level for sodium is 2300 to 6900 ppm Na. All the results of sodium in Table 8.11.3-5 are below this toxic range. Continued plant analysis and visual observations are recommended since sodium levels in the soil and irrigation water are high; see Table 8.11.3-3. According to Richards (1954) boron concentrations above 250 ppm are usually associated with boron leaf toxicity. Boron levels presented in Table 8.11.3-5 are highly variable yet they are well below this toxicity criterion. The highest boron

concentrations were in the big sagebrush; however, no damage is visible during field observation.

Sodium and boron toxicities are more easily monitored because the plants show visible signs of damage. Fluoride is more difficult to trace because many plants do not show symptoms of fluoride toxicity. Because excess fluoride levels are not visible and the observed levels are nearing the maximum limit, particular attention should be given to fluoride in future monitoring. Dilution and winter leaching are important factors which reduce fluoride accumulation and reduce the likelihood of exceeding the tolerance limits.

8.11.3.6 Summary and Conclusions

Mine drainage water was disposed over 100 acres of native vegetation with minimum disruption of the environment during 1980 and 1981. Sprinkling using gun sprinklers was begun in mid-July and continued to mid-October 1980 and from June through September 1981. Using the information developed during the 1980 season, minor system operational adjustments were implemented to minimize any adverse effects on the environment.

Minor adjustments made in the scheduling of irrigation essentially eliminated deep percolation. A water use curve presented in the 1980 report similar to Figure 8.11.3-1 was used as a guide for scheduling irrigations and estimating the area necessary for disposing the mine effluent through sprinkling. Accurate radiation and temperature data were collected at the C-b Tract and used to develop the curve in Figure 8.11.3-1 of this report.

From Figure 8.11.3-1 it appears that it may be possible to use a constant average disposal rate of approximately 3.0 gpm/acre from mid-April through September without creating appreciable deep percolation. Thus, to keep two sprinklers operating continuously for the entire period, a disposal area of approximately 150 acres (440 gpm/3.0 gpm/ac) is needed.

Soil water contents were checked periodically with a neutron probe after each irrigation to adjust the schedule. Deep percolation can be detected by noting when water contents at maximum depths immediately following irrigation are above 35%. On the average the available soil water storage is about 12.0 cm, thus the standard 12 hour irrigation setup time which gives an application amount of 8.0 cm appears reasonable for the general project treatment. Constant soil water content readings with time and depth downslope of the sprinkled areas indicated that there was practically no lateral seepage.

Chemical concentration levels in plant tissues and most soil characteristics are below their respective toxic limit ranges. However, soil ESP was near the critical limit, so careful visual observation of plant foliage for signs of salt damage is recommended. If irrigation should be discontinued, special attention should be given to plant stress due to specific ion toxicity and salt concentration as soil moisture levels decline.

Fluoride levels in the tissues of some species of plants are approaching levels which would be considered toxic to animals consuming them as a continued and the main source of feed. However, this would not be the case for animals migrating in and out of the sprinkled area and/or consuming a variety of plant species. Foliar fluoride concentrations should be measured after each irrigation cycle in the standard treatment area as levels which may be toxic to grazing animals do not affect the plants so are not visible as is the case for boron and sodium.

8.11.4 Deer Reflector Study

C.B. in cooperation with the DOW, OSO, DOE, C-a Tract, and Multi Minerals Corp is testing a new type of wildlife reflector along the Piceance Creek Highway. The reflector was designed in Austria and tested in Europe. The results showed that they reduced deer/vehicle collisions by 80% or more. However, these tests did not consider the influence of weather effects on the number of roadkills. Therefore, we have designed tests to reduce the bias of weather on the study.

Regarding study design, four-one mile sections of road were selected based on the number of roadkills along the highway. Reflectors were spaced every 66 feet on both sides of the road. Two types of reflectors were used: one for use in flat areas and one for sloping roadsides. The times the reflectors will be activated will be alternated. Two sections will be activated for a week, then covered for a week. The other two sections will be activated when the first two are covered.

When the headlights of an approaching vehicle strike reflectors they reflect a red light into the adjoining terrain and an optical warning fence is produced. This reflected light cannot be seen by the driver. However, any approaching deer are alerted which, hopefully, stop or retreat away from the road. Immediately after the vehicle passes, the reflectors become inactive permitting the animals to cross safely.

These reflectors will probably be required to be tested two field seasons to adequately assess their effectiveness.

8.12 Quality Assurance

Quality assurance for both vegetation and wildlife studies is implemented primarily by the following five procedures:

1. Field checks of measurement procedures.
2. Examination of raw data sets for consistency of format and data magnitude.
3. Spot check of data output from remote computer terminal.
4. Spot check of data output from computer data base.
5. Verification of reduced and analyzed data in final report.

These procedures are elaborated below.

Field checks of measurement procedures - New personnel are accompaned in the field by experienced workers. After a sufficient training period, such personnel are sometimes permitted to work alone. The resident

environmental scientist, however, consistently makes field checks in the event he cannot participate in the data collection himself.

Examination of raw data sets for consistency of format and data magnitude - All field data are recorded on standard forms, which list the observer, date, other relevant information, and the raw data. Data values are checked to be sure they are of the appropriate magnitude and have been recorded in the proper units of measurement.

Spot check of data output from main computer storage - Data filed in the remote computer terminal are sent to a main computer for archival storage. Data sets are spot checked once again to insure correct transfer.

Verification of reduced and analyzed data in final report - The final report is compared with the original draft to check for typographic errors.

9.0 ITEMS OF AESTHETIC, HISTORIC, OR SCIENTIFIC INTEREST

9.1 Aesthetic Values

The C-b Annual Summary and Trends Report (November 1974 through October 1975) described a study which determined the type and quality of scenic resources in the Tract area. It was concluded that the Piceance Creek Basin has a low scenic value when compared to the other landscape types of the region. Restated, on a regional basis the Piceance Creek Basin has an extremely low visual character. However, a concerted effort has been made to paint and locate new structures to reduce any adverse aesthetic impact.

9.2 Historic and Scientific Values

A detailed baseline study of the cultural resources of Tract C-b has been conducted to identify sites of past human activity. (See Volume 1 of the Final Report of the Environmental Baseline Program.) Three historic sites exist on the Tract, (5RB136, 5RB146, and5RB147) and have been reported therein. Every site of disturbance is thoroughly investigated by the on-site environmental manager for historic or scientific value. Additional disturbance in 1981 was minimal and no additional discoveries were found.

10.0 INDUSTRIAL HEALTH, SAFETY AND SECURITY

10.1 Scope and Rationale

The health and safety of employees at the Cathedral Bluffs project is regulated according to 30 CFR, Part 57, by the Mine Safety and Health Administration under the Mine Safety and Health Amendments Act of 1977. In addition, the project is regulated by the Colorado State Division of Mines.

Periodic reports on Health and Safety Activities are forwarded to the Oil Shale Supervisor. Such reports are those prepared by the C.B. Project and all contractors for distribution to outside Federal and State agencies, i.e., Mine Safety and Health Administration (MSHA) and the Colorado Division of Mines and inspection reports made by these agencies and received by the Project and all contractors at the C.B. site. These reports relate to accident frequency analyses, inspection reports and responses, health and safety training, variance reporting, and shaft gas analysis. Inasmuch as accident frequency analysis and shaft gas analysis relate to monitoring, they are discussed below.

10.2 Accident Frequency Analysis

Table 10.2-1 presents monthly data on manhours, reported accidents (RA), lost-time accidents (LTA) and incident rate (IR) for on-site C.B. staff and contractor personnel.

Incident rate is defined as:

$$IR = \frac{\text{Number of Reportable Accidents} \times 200{,}000}{\text{Hours of Employee Exposure}}$$

The total manhours, accident numbers and incident rate for the year 1981 at C-b Tract are as follows:

	Manhours	Reportable Accidents	Lost Time Accidents	Incident Rate
C.B.	231,020	1	1	0.9
Contractors	734,616	35	21	9.53
TOTAL	956,636	36	22	7.53

The incident rates for 1979 and 1980 were 1.90 and 5.10 respectively for C.B. and contractors combined.

10.3 Shaft Gas Analysis

Weekly average values of methane (percent) as measured at the collars of the Ventilation/Escape and Production/Service Shafts are presented in Table 10.3-1. Maximum weekly average value (0.118 percent) to date occurred in the V/E Shaft during the week of July 16-21, 1981. Maximum weekly average in the Production/Service Shafts has been 0.024 percent (June 18-25, 1981).

TABLE 10.2-1

Monthly Accident Rates

1980	C.B.									CONTRACTOR									C.B. & CONTRACTOR								
	MAN HOURS				ACCIDENTS			I.R.		MAN HOURS				ACCIDENTS			I.R.		MAN HOURS				ACCIDENTS			I.R.	
	MONTH	Y.T.D.	QRTR.	mon RA	yld RA	mon LTA	yld LTA	mon IR	yld IR	MONTH	Y.T.D.	QRTR.	mon RA	yld RA	mon LTA	yld LTA	mon IR	yld IR	MONTH	Y.T.D.	QRTR.	mon RA	yld RA	mon LTA	yld LTA	mon IR	yld IR
JAN.	16,335	16,835		0	0	0	0	0	0	48,050.5	48,050.5		2	2	2	2	8.32	8.32	64,885.5	64,805.5		2	2		2	6.16	6.16
										G 38,864 O 9,186.5			2 0	2 0	2 0	2 0											
FEB.	18,049.5	34,884.5		0	0	0	0	0	0	G 40,002 O 8,399.5			1 1	3 1	1 1	3 1			56,451	131,336.5		2	4	2	4	6.08	6.09
										48,401.5	96,452		2	4	2	4	8.26	8.29									
MAR	17,643.5	52,528		1	1	1	1	11.33	3.81	50,744	147,196		3	7	3	7	11.82	9.51	68,387.5	199,724		4	3	4	8	11.70	8.01
			52,528							G 40,128 O 10,616		147,196	1 2	4 3	1 2	4 3					199,724						
APR	18,550	71,078		0	1	0	1	0	2.81	59,981	207,177		3	10			10.00	9.65	78,531	278,255		3	11			7.64	7.91
										G 47,569 O 12,412			3 0	7 3	3 2	7 3											
MAY	17,036	83,164		0	1	0	1	0	2.27	G 37,219 O 15,233.5	259,629.5		2 1	9 4	2 1	9 4			69,538.5	347,793.5		3	14			8.63	8.05
										52,452.5			3	13			11.44	10.01									
JUN	23,907.5	112,071.5		0	1	0	1	0	1.78	49,349.5	308,979	308,979	3	16	2	15	12.16	10.3	73,257	421,050.5		3	17			8.19	8.08
										G 35,641 O 13,708.5			1 2														
JUL	16,404.5	128,476		0	1	0	1	0	1.56	72,478	381,457		4	20	1	16	11.04	10.49	88,882.5	509.933		4	21	1		9.00	8.24
										G 42,607 O 29,871			4 0														
AUG	17,640.5	146,116.5		0	1	0	1	0	1.37	66,982	448,439		2	22	2	18	5.97	9.81	84,622.5			2	23			4.73	7.74
										G 30,409 O 36,573																	
SEP	17,604	163,795		0	1	0	1	0	1.22	72,012	520,451	520,451	3	25	3	21	8.33	9.61	89,616	684,171 5		3	26			6.70	7.60
			51,649							G 31,626 O 40,386			2														
OCT	25,141	188,860 5		0	1	0	1	0	1.06	54,429	574,880		6	31 6	31		22.05	10.78	79,570	763,7415		6	32			15.0	8.38
										G 20,578 O 33,851			3 3														
NOV	23,935	312,795.5		0	1	0	1	0	.94	75,926.5	650,806.5		1	32		21	2.63	9.8	99,861.5	863,603		1	33			20	7.6
DEC	18,557	531,352.5		0	1	0	1	0	.09	83,810.5	734,617		3	35		21	7.15	9.53	102,367	965,970.5		3	36			5.8	7.45

TABLE 10.3-1

V/E and Production/Service Shafts
Gas Analysis Weekly Summary

DATE	V/E Shaft	Production/Service Shaft
1/05/81 - 1/09/8.	.103	.008
1/09/81 - 1/15/81	.115	.003
1/22/81 - 1/29/81	.083	.013
1/30/81 - 2/05/81	.1	0
2/06/81 - 2/12/81	.065	.015
2/12/81 - 2/17/81	.082	.020
2/19/81 - 2/25/81	.093	.011
2/26/81 - 3/04/81	.088	.020
3/05/81 - 3/10/81	.104	.019
3/11/81 - 3/18/81	.104	.003
3/20/81 - 3/26/81	.099	.001
3/26/81 - 4/01/81	.108	.002
4/03/81 - 4/08/81	.089	0
4/08/81 - 4/14/81	.107	.003
4/15/81 - 4/22/81	.106	.002
4/23/81 - 4/28/81	.090	.007
4/30/81 - 5/06/81	.099	.008
5/07/81 - 5/13/81	.111	0
5/14/81 - 5/19/81	.088	.002
5/20/81 - 5/27/81	.077	.006
5/28/81 - 6/03/81	.107	.007
6/18/81 - 6/23/81	.099	.024
7/01/81 - 7/07/81	.111	0
7/08/81 - 7/15/81	.114	0
7/16/81 - 7/21/81	.118	0
7/22/81 - 7/29/81	.11	0
8/06/81 - 8/12/81	0	0
8/13/81 - 8/19/81	0	0
8/20/81 - 8/26/81	.1	0
9/17/81 - 9/23/81	0	0
9/24/81 - 9/30/81	.04	0
10/01/81 - 10/07/81	.04 to .03	0
10/08/81 - 10/14/81	.03	0
10/15/81 - 10/21/81	0	0
10/23/81 - 10/28/81	0	0
10/29/81 - 11/03/81	0	0
11/05/81 - 11/11/81	0	0
11/12/81 - 11/19/81	0	0
11/19/81 - 11/25/81	0	0
11/26/81 - 12/03/81	0	0
12/04/81 - 12/10/81	0	0
12/11/81 - 12/17/81	0	0
12/18/81 - 12/24/81	0	0
12/25/81 - 12/31/81	0	0

11.0 SUBSIDENCE MONITORING

The overall objective of the subsidence monitoring program is to determine the effects of underground excavations on the ground surface and on mining levels.

The surface and underground subsidence caused by mining activities cannot start until significant underground development out from the shaft pillar areas occurs. Dewatering is not a valid subsidence- inducing mechanism for the C-b Tract area for the following reasons:

1. The porosity of oil shale rocks at C-b is low (approximately 1-3%) in the aquifers being dewatered, thus consolidation of the aquifer zones, which is the cause of subsidence, does not or will not occur. As relationship of load bearing capacity of the contained liquid and the adjacent rock control this phenomenon, a low porosity precludes any settlement.

2. Confined and pressured aquifers can result in subsidence when overlying rock is supported by fluid pressures. This is not the situation at C-b.

As indicated on Figure 3-3 of Volume 1 the geotechnical program of which subsidence considerations are an integral part is to be initiated in the second quarter of 1983.

This monitoring program is to provide information and a record of the behavior of the ground surface and rock adjacent to the underground excavations. This informaation is needed for several purposes for the mining effort as well as to provide safe operating conditions. This monitoring program is to:

1. provide the capability of observing unusual situations during mining and retorting so that remedial measures can be instituted; and

2. to formulate guidelines for future mining and retorting efforts for development of the Tract.

12.0 ECOSYSTEM INTERRELATIONSHIPS

12.1 Introduction

The driving variables of an ecosystem are abiotic phenomena. The abiotic components directly affect the biotic components (primary and secondary producers and decomposers) of the system. Ecosystem interrelationships are the interactions between the abiotic and biotic components of an ecosystem.

Several of these biotic components have been identified as indicator variables (discussed in Chapter 3). Indicator variables are variables or processes with the potential to respond to disturbances or that are subject to federal or state regulations. Activities involved with oil shale development (including construction, mining, retorting, raw shale storage, process shale disposal, water management, reclamation, and others) can also act as driving variables.

12.2 Objectives

The objectives of investigating ecosystem interrelationships are to use data obtained from monitoring indicator variables in identification of relationships, to establish the range of natural variability in the relationships, to determine if these relationships are affected by commercial development of the Tract, to attempt to identify ecosystem functional relationships that may show response to natural or man-made perturbations in advance of measured responses in indicator variables, and to obtain preliminary information on ecosystem resiliency to natural or man-made perturbations.

12.3 Candidate Interrelationships

Several ecosystem interrelationships involving indicator variables were identified. These include:

1. the relationship between climatic variables and annual herbaecous production;
2. the relationship between deer road kill on Piceance Creek Road and traffic and/or deer density;
3. the relationship between the three major indicator variables used to monitor changes in deer population and distribution. These indicators are pellet group count, browse production and utilization, and deer road counts;
4. the relationship between herbivore density and indicator variables used to monitor deer population;
5. the relationship of deer mortality with
   a. deer density as estimated using browse utilization and pellet group density as indicator variables, or
   b. climatic variation including age-specific and sex-specific mortality;
6. the relationship between water quality and benthos and periphyton densities; and
7. the relationship between concentrations of boron and fluoride in water and concentrations in plants using the water.

Analysis of ecosystem interrelationships consisted of qualitative and quantitative phases. The qualitative phase seeks to determine the

importance of interrelationships on a descriptive basis without statistical analysis (due to incomplete or insufficient data). The quantitive phase includes statistical analyses where data are sufficient.

The relationships identified above were selected for qualitative analysis to aid in identification of environmental impacts of commercial development on some major components of the ecosystem. The first three relationships have been further selected for initial quantitative analysis.

These candidate interrelationships will continue to be reviewed for validity and usefulness as data are accumulated. In addition, new ecosystem interrelationships may be identified for further investigation based on existing data and different stratification schemes to develop hypotheses appropriate for statistical analysis. The following list comprises candidate interrelationships that may be in the latter category.

1. Relationships between abiotic variables measured at the microclimate station and the meteorological tower or air quality sites.
2. The relationships of populations of small mammals, lagomorphs, or birds with climate variables or general vegetation condition.
3. The relationship between climatic variables and shrub production.
4. The relationship between benthos or periphyton measurements and streamflow or climatic variables.

12.4 Analysis of Selected Ecosystem Interrelationships

12.4.1 Experimental Design

Ecosystem interrelationships are not necessarily measured directly, but may be identified by inferences based on the basic principles of ecology. Augmented with knowledge gained by monitoring and analysis of indicator variables since baseline, these inferences allow the development of hypotheses that can be subjected to statistical tests.

12.4.2 Effects of Climatic Variation on Vegetative Productivity

12.4.2.1 Scope

It is hypothesized that vegetative productivity increases with increased precipitation and increased length of the growing season. To test this hypothesis, climatic data were collected. Precipitation measurements included:

1. Total annual precipitation of the current year.
2. Total annual precipitation of the previous year, especially late season precipitation.
3. Total annual precipitation of the previous growing season - from April through March.
4. Precipitation temporal distribution during the growing season over:
   a. March - April - May, or
   b. April - May - June, or
   c. May - June - July.
5. Abnormal rates of precipitation.

Growing season measurements include:

1. Length of the growing season,
2. Total degree days during the growing season,
3. Degree day temporal distribution over:
   a. April - May - June
   b. May - June - July
   c. June - July - August
   d. July - August - September
   e. Over the growing season

12.4.2.2 Objectives

The objective of this study is to statistically analyze the interrelationships of vegetative productivity with amount and temporal distribution of precipitation, length of growing season, and degree days during the growing season.

As more data are accumulated, attempts may be made to identify ecosystem functions that may respond to environmental change or serve as indicator processes that represent the responses of groups of indicator variables. Monitoring could be economized if an ecosystem function were shown to be representative of an entire set of indicator variables.

Following is a discussion of the interrelationships currently being analyzed.

12.4.2.3 Method of Analysis

Monthly precipitation data are occasionally lost due to instrument malfunction. When this occurs, between-station precipitation regressions are performed in order to supply a monthly estimate of missing values. These estimates are inappropriate but necessary to obtain an annual precipitation total for each station (see Section 6.3.1).

Sites selected for herbaceous productivity measurements were: BJ22 - Chained Pinyon-Juniper (control site), BJ25 - Pinyon-Juniper Woodland (future disturbance, current control). For site locations, see Exhibit C (cover jacket).

12.4.2.4 Results and Discussion

Productivity and each of the variables of possible association (listed above) were examined for possible correlations. All parameters except degree days displayed a positive correlation with productivity.

The highest correlation coefficients were vegetative productivity associated with the precipitation received in the previous growing season year at the productivity sites (BJ22, BJ25). High correlations were also found for spring precipitation at the productivity sites. Chained pinyon-juniper community displayed greatest sensitivity to this factor. Figures 12.4.2-1a and 1b are plots of these correlations with a least squares regression line calculated for each.

FIGURE 12.42-1a PLOTS OF PRODUCTIVITY VS. APRIL - MAY - JUNE PRECIPITATION TOTALS

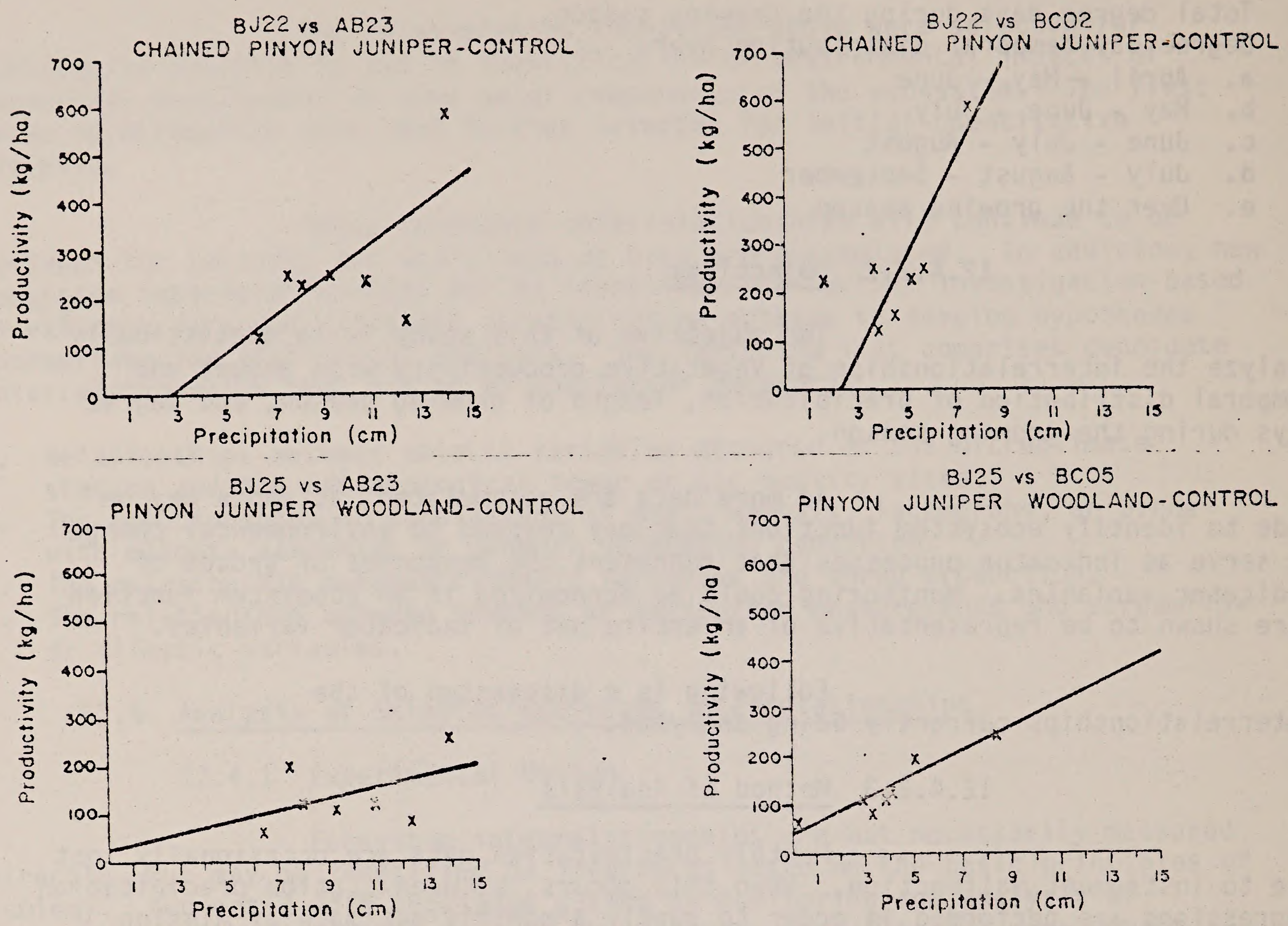
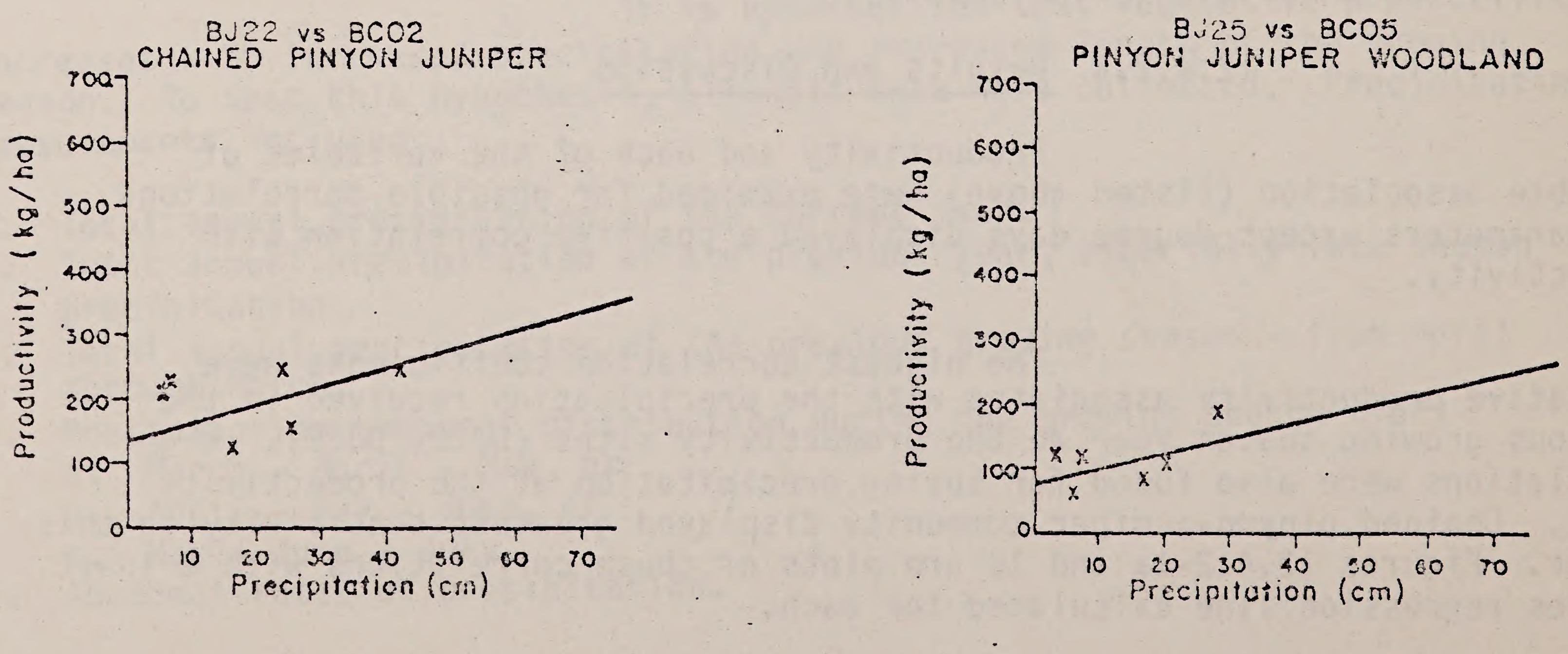


FIGURE 12-4.2-1b

PLOTS OF PRODUCTIVITY VS. PREVIOUS GROWING SEASON YEAR PRECIPITATION*



* Total Precipitation in Previous Year Starting in April. (thru March)

12.4.2.5 Conclusions

Climatic parameters displaying strongest correlation with vegetative productivity were precipitation received during the previous growing season year (April 1 through March 31), and spring precipitation of the current year.

Chained pinyon-juniper productivity was the most sensitive to growing season rainfall.

12.4.3 Effects of Deer Density and Traffic on Deer Road Kill

12.4.3.1 Scope

The factors thought to have greatest influence on deer road kill are density of the deer traffic on various segments of Piceance Creek Road and climate. Weekly road counts of deer and road kill are conducted from mid-September through May while deer are on Tract. Data collection began September 1978 and is ongoing.

12.4.3.2 Objectives

The two major objectives of this study are first to determine the existence of interrelationships between road kill, deer density and traffic. If interrelationships are determined to exist, then the strength of correlation is examined. The second major objective is to use knowledge gained of interrelationships between these variables to aid in the formulation of mitigative measures.

12.4.3.3 Experimental Design

Weekly samples of deer road count and road kill are collected each year from mid-September through May when deer are on Tract (deer migrate from Tract to highlands in summer months). Deer count and road kill tabulations are completed for one mile intervals on a 41 mile segment of Piceance Creek Road between Rio Blanco and White River City (Highway 64). Traffic counters are placed on access road entrances to C-b and C-a Tracts, and on Piceance Creek Road near Rio Blanco and White River City and between the two Tracts. A count of incoming vehicles (excluding buses) is kept at the C.B. guard gate.

12.4.3.4 Method of Analysis

Linear regression analyses of road kill as a function of deer density (deer count), vehicle count, and both deer count and vehicle count were performed. From these calculations existence and strength of correlation were obtained. The data were grouped and analyzed by completed season and for entire study period from September 1978 to present.

12.4.3.5 Results and Discussion

Table 12.4.3-1 summarizes the results of the regression analyses. Correlations were found to exist between deer kill and

TABLE 12.4.3-1

Deer Kill Regression Analysis

Dependent Variable	Independent Variable	Time Period	r^2	Correlation
Deer Kill	Deer Count	9/78-12/81	0.20	Positive
	Vehicle Count	9/78-12/81		No linear correlation
	Deer Count Vehicle Count	9/78-12/81	0.53	Deer Count Positive Vehicle count Negative
	Deer Count	9/79-05/80	0.50	Positive
	Vehicle Count	9/79-05/80		No linear correlation
	Deer Count & Vehicle Count	9/79-05/80		No linear correlation
	Deer Count	9/80-05/81	0.18	
	Vehicle Count	9/80-05/81		No linear correlation
	Combined	9/80-05/81		No linear correlation

Tested at the 0.05 level of significance.

deer count at a five percent level of significance for all time periods tested. A correlation was found for deer kill and deer count/vehicle count for the duration of the period. All these correlations were extremely weak.

12.4.3.6 Conclusion

Though no formal study nor statistical analyses have been performed, trends in road kill data indicate that road kill is influenced by weather condition. Harsher winter seasons force the deer closer to the road, increasing the likelihood of deer/vehicle collision. Results indicate that deer herd size and weather conditions have greater influence on road kill than amount of traffic.

12.4.3.7 Deer Reflector Study

Deer road kill numbers seemed to be of enough significance to warrant mitigative measure. C.B. in cooperation with DOW, OSO, DOE, C-a Tract and Multi Minerals Corporation, has initiated a mitigation study using deer reflectors.

The reflectors are designed to reflect red light on the sides of the road when headlight beams contact them. The theory behind this study is that the reflections will caution the deer, causing them to delay crossing the road until the vehicle has passed and the light reflection disappears.

It is anticipated that two seasons of testing will be required in order to accumulate enough data to determine effectiveness of the reflectors.

12.4.4 The Relationship Between Major Indicator Variables Used to Monitor Changes in Deer Population and Distribution

12.4.4.1 Scope

Browse utilization and pellet group count across a spectrum of vegetative communities is used to determine the density of deer populations and habitat preference. Strong correlation between browse production/utilization, pellet group census, and road count is desired to insure accuracy of deer population estimates and habitat preferences derived using these sampling methods.

12.4.4.2 Objectives

The objective of studying these relationships is to determine if browse production/utilization, deer pellet group census, and road count yield similar estimates of deer population fluctuations. Close agreement would allow detection of relatively small changes in deer population and localized distributions.

12.4.4.3 Method of Analysis

Linear regression analyses were performed for each combination of indicator variables to determine strength of relationship.

12.4.4.4 Results and Discussion

Correlations were found for all combinations of variables at the five percent level of significance (see Table 8.2.7-2). A high correlation between road count and pellet group count was found when 1978-79 data are omitted (omission due to severity of winter causing climatological bias). Other combinations produced weaker correlations. Several of the correlations were negative.

The time period of analysis is five years, a small sample size for evaluation of between-year variation. Analyses were initiated regardless of the short time period due to the importance of the study objective. The small amount of data available for analyses may strongly contribute to the weak relationships found.

12.4.4.4 Conclusion

Weak correlations appear to exist between road counts, pellet counts, and browse production and utilization. Several more years of data are required before definitive conclusions can be obtained.

12.4.5 Studies Incorporating Qualitative Analyses

12.4.5.1 The Relationship Between Deer Density and Indicator Variables Used to Monitor Deer Population

12.4.5.1.1 Objectives

The objectives of this study are: To evaluate interrelationships between deer density and browse utilization, deer pellet group census, and deer road count, to provide data for a quantitative analysis of the relationship of these three indicator variables. The comparison study is designed to further determine their value as indicators of deer density and movement (see Section 12.4.4).

12.4.5.1.2 Method of Analysis

Qualitative analysis is used to identify trends in data indicating effects of commercial development activities on deer use of the Tract. Deer use level is inferred through fluctuations in browse utilization, pellet group census, and deer road count. Trends are identified by between-year regression analysis of each of the variables.

12.4.5.1.3 Conclusions

No fluctuations in deer population or movement caused by commercial development of the Tract can be identified from analysis of these three indicator variables.

12.4.5.2 The Relationship Between Deer Mortality and Deer Density and/or Climatic Variation

12.4.5.2.1 Objective

The objective of this study is to determine if a correlation exists between deer mortality, and deer density and/or climatic variation.

12.4.5.2.2 Method of Analysis

Pellet group count, deer road count, and browse utilization are used as indicators of deer density. These data and climatic variation are compared to mortality count data collected each spring from established transects in known areas of high mortality (primary wintering areas).

12.4.5.2.3 Conclusion and Discussion

Qualitative analysis indicates that a correlation may exist between deer mortality and density and climatic variation. Data are not yet sufficient for quantitative studies.

12.4.5.3 Relationship Between Water Quality and Aquatic Animal and Plant Densities

12.4.5.3.1 Objective

The objectives of this study are to enable inference of water quality from benthos and periphyton taxonomic composition, relative abundance, diversity, and biomass; and to identify potential impacts of commercial development on other components of the aquatic system using benthos and algae as early indicators of stress.

12.4.5.3.2 Method of Analysis

Between-year seasonal trends in composition, relative abundance, diversity, and biomass of benthos and periphyton are compared. Density, relative abundance indices, and the Shannon-Weiner diversity indices are completed to identify changes in benthos and periphyton populations.

12.4.5.3.3 Conclusions

No qualitative changes in benthos and periphyton populations have been identified. Quantitative analyses of relationships between water quality and benthos and periphyton populations are precluded due to insufficient data.

12.4.5.4 Relationship Between Concentrations of Boron and Fluoride in Water and Plants

This study is discussed in 8.3.11 with respect to sprinkler irrigation.

12.4.5.2 The Relationship Between Deer Mortality and Deer Density and/or Climatic Variation

12.4.5.2.1 [illegible]

[illegible] determine if a correlation exists between deer mortality, and deer density and/or climatic variation.

12.4.5.2.2 [illegible]

[illegible] and browse utilization are used as indicators of deer density. Measures of climatic variation are compared to mortality count data collected each spring from established transects (a measure of mortality in primary wintering areas).

12.4.5.2.3 [illegible]

Qualitative analysis indicates that a correlation may exist between deer mortality and [illegible] climatic variation. Data are not yet sufficient for quantitative studies.

12.4.5.3 [illegible]

[illegible]

[illegible] enable inclusion of [illegible] composition, relative abundance, diversity and biomass, and to identify potential impacts of [illegible] development on other components of the aquatic system using benthos and algae as early indicators of stress.

12.4.5.3.2 Method of Analysis

[illegible] composition, [illegible] Shannon-Weiner diversity indices and [illegible] and periphyton populations.

12.4.5.3.3 Conclusions

[illegible] period [illegible] relationships [illegible] precluded due to [illegible]

12.4.5.4 [illegible] Concentrations of Boron and Fluoride in Water and Plants

[illegible] particular irrigation.

13.0 DATA MANAGEMENT AND REPORTING

13.1 Introduction and Scope

The systems and procedures used to process, manage, analyze, and report large quantities of data are described in this chapter. These systems and procedures are applicable to environmental, health, and safety data collected under the Development Monitoring Plan.

13.2 Data Processing and Control

Data processing and control consist of the actions performed on the data as it flows from collection point to reports and permanent storage. These actions are described as data flow procedures and data control.

13.2.1 Data Flow

Field technicians collect data on a schedule determined by the Monitoring Plan. Collected data are delivered to the Management Information Systems (MIS) Department or to the Water Quality Analysis Laboratory where chemical analyses are performed and the results then delivered to the MIS Department. Data are received in the MIS Department by the Data Preparation Coordinator who enters it into the Data Log and assigns a library code. Data requiring further reduction are scheduled and assigned to a Data Assistant for chart interpretation and/or preparation for data entry into the computer. All data are keyed to disk as soon as they are ready, verified and then entered into appropriate files maintained in the Environmental Data Base Management System (DBMS). Data are selectively retrieved from data bases for analyses and reporting. The computer data base provides for permanent data storage. Backup computer files are maintained to ensure against loss of data.

13.2.2 Data Control

Data control consists of those steps in the data processing flow to insure that integrity of data will be maintained. These steps include visual scanning of data for obvious errors and omissions at the time of log-in by the Data Preparation Coordinator and again prior to keypunching. Keypunch verification is attained by second keypunch processing by a second person.

Completeness of data received is determined at time of log-in by use of checklist of scheduled data collection by individual sampling station developed from the Monitoring Plan. A complete list of sampling stations and identifying codes for computer screening is used to provide the means for statusing and identifying data.

These stations and codes are shown in Appendix 2A, Table A2.2-1.

Further checks on data quality are described later under Quality Assurance.

13.3 Data Base Management

Two data base management systems are currently used to store, maintain, and make environmental data accessible through the computer. These are Rapid Access Management Information System (RAMIS II) and a government maintained system known as Water Storage and Retrieval System (WATSTOR).

All computer compatible environmental data are currently prepared and entered into RAMIS where they are maintained as sets of files of common data types. Data collected by the United States Geological Survey (USGS) are processed by government agencies and stored in WATSTOR. Retrievals of data from WATSTOR are made by telephone dialup to the system.

Table 13.3-1, Status of Automated Environmental Data Base, provides a list and status of the RAMIS files by data type. Each file contains a set of measured variables with date and other identifying information.

13.4 Data Analyses

Data analyses are used to determine potential impacts of oil shale development on the environment. Statistical and graphical analyses are utilized to determine if changes or trends from baseline conditions have occurred.

13.4.1 Inferential Statistical Analyses

These analysis include time series, correlation and regression, and other parameters methods applicable to the particular study. Established computer programs are used for the designated statistical test or model.

13.4.2 Descriptive Statistical Analyses

Descriptive statistics are used with professional judgment to determine if the environment has been affected by development activity. No hypotheses are tested or inferences made in the statistical sense with descriptive statistics. Descriptive statistics may include mean, mode, median, variance, and range. They are used when the underlying assumptions of a particular statistical test or model cannot be assumed.

13.4.3 Graphics

Charts, histograms, and plots are used to provide visual analyses and comparisons. These analyses are descriptive and therefore professional judgment is used in interpreting the graphicial analyses.

13.5 Quality Assurance Procedures

Quality Assurance for monitoring and data processing are in accordance with procedures recommended by the Environmental Protection Agency. These procedures include appropriate sampling, storage and analysis techniques, accurate record keeping of sample history, results, and data review.

TABLE 13.3-1

Status of Automated Environmental Data Base

	Automated
Water Quality	
Springs and Seeps	October, 1974 thru November, 1981
Alluvial Wells	October, 1974 thru November, 1981
Upper Aquifer Wells	October, 1974 thru November, 1981
Lower Aquifer Wells	October, 1974 thru November, 1981
Wells Water Levels	
Water Levels	October, 1974 thru November, 1981
Water Augmentation Plan	
Springs and Seeps	July, 1979 thru November, 1981
Upper Aquifer Wells	August, 1979 thru November, 1981
Lower Aquifer Wells	August, 1979 thru November, 1981
Precipitation	January, 1979 thru November, 1981
National Pollutant Discharge Elimination System	
Water Quality Data	July, 1979 thru November, 1981
Water Usage	October, 1974 thru December, 1981
Well Reinjection	March, 1981 thru November, 1981
Air Quality	
Small Stations (Station AD42, AD56)	October, 1974 thru August, 1980
Large Trailer (Station AB20)	October, 1974 thru October, 1976 July 1978 thru October 1981
Large Trailer (Station AB23)	October, 1974 thru October, 1981
Meteorological Tower (Station AA23)	October, 1974 thru October, 1981
Traffic	February, 1980 thru November, 1981
Biology	
Microclimate	October, 1974 thru November, 1981
Deer Kill	October, 1974 thru November, 1981
Deer Count	September, 1977 thru November, 1981
Avifauna	1977 thru 1981

Data collected and analyzed by USGS for stream flow and stream water quality are stored in government computer data bases in Reston, Virginia. These data bases (WATSTOR) and (NAWDEX) are accessed by dialing computer communications for retrievals of data to the Occidental Grand Junction computers for printing and analysis..

13.5.1 Outlier Detection

Both descriptive and inferential statistical outlier tests are used to detect extreme values in environmental data. Before any statistical outlier test is performed, the assumptions of that particular test or model associated with the problem of interest will be tested for validity. The statistical outlier program is in the checkout phase; it is planned to integrate into operational procedures in 1982.

13.5.2 Compliance Monitoring

Compliance monitoring is done to assume compliance with conditions of the Lease, Federal, State, and local regulations. To achieve this end, a program of regular assessment inspections are made to monitor all phases of compliance. Data logs and computer data base status reports are examined as part of this procedure.

13.6 Data Reporting

The following reports are prepared through the use of computers and services from the Management Information Systems Department.

13.6.1 Monthly Reports

Monthly air and water quality reports are generated internally and consist of required monitoring variables. Air is monitored continuously, while water is sampled weekly, monthly, quarterly and semiannually depending upon the water sampling station and specific variable.

13.6.2 Compliance Reports

All C.B. data collected within a six month period are reported to the OSO semiannually in partial fulfillment of Lease compliance. These reports contain both environmental and health and safety data. Air, water, environmental noise and biology data are included in environmental monitoring whereas traffic, mine gas and accident frequency are included in health and safety monitoring.

13.6.3 Annual Report

The annual report is an indepth analyses report for all areas of environmental concern. This report includes analyses by visual interpretation of graphics, time series analyses, inferential as well descriptive statistical analyses and analyses derived from mathematical models.

13.6.4 Graphic Reports

13.6.4.1 Time Series Plots

Time series plots of indicator variables for air, water, meteorological and biological data are included in the six month C.B. semiannual reports.

13.6.4.2 Frequency Distributions

Frequency distributions for air and water quality data are included in the monthly reports. Additional frequency distributions appear in the annual report.

13.6.4.3 Draw-Down Curves

Computer prepared draw-down curves or piezometric surfaces are included in the 1980 annual report to depict effects of dewatering of the shafts as derived from well-levels data.

13.6.4.4 Wind Roses

Quarterly wind-rose and wind-direction-only plots are included in the semiannual and annual reports. Wind roses show a percent concentration by wind speed and direction; wind-direction-only roses show percent of total wind speed occurring in a specific direction.

13.6.4.5 LANDSAT

The purpose of LANDSAT is to assist in the determination of general vegetation condition.

Multi Spectral Scanner (MSS) data are obtained from the LANDSAT Computer Compatible Tapes (CCTs). Software is then utilized to retrieve the area of interest from the tape. The data are then geometrically corrected. A transformation is performed to calculate vegetation indices from image data. The vegetation indices are related to green biomass through a calibration curve developed from clipping data correlated with scanner data. Indices from two different image dates are differenced to determine change detection. Output is presented in the form of gray maps which are produced by a line printer.

13.7 Computer Hardware and Software

13.7.1 Computer Hardware

Large mainframe computers (IBM 3033, Control Data 7600, and CRAY) are accessed by means of Data 100 Remote Job Entry terminal equipment and by on line interactive terminals for all data processing and analyses. These computers reside in Occidental Petroleum Corporation Data Center in Houston and in United Information Systems Data Center in Kansas City. High speed leased data lines and modems are used in the communications network. Output devices include (2) three hundred line-per-minute printers, line plotter with four pens, and interactive terminal printers and hardcopy units.

13.7.2 Computer Software

Many computer software systems and special purpose application programs are used in data processing, analyses, and reporting. Most notable of these include Rapid Access Management Information System (RAMIS), Statistical Analysis System (SAS), California Products Graphics System (CALCOMP), and Contour Plotting System (CPS1).

13.8 Data Availability

All environmental data are available to the public. All data are reported to the Oil Shale Office in Grand Junction. These reports may be examined in that office during normal working hours. Magnetic tapes containing data in the Computer Data Base are also provided to the Oil Shale Office.

14.0 NOTES

14.1 Conversion Factors

An attempt has been made to report all studies and data in metric units with the exception of hydrology. In most cases these data are collected and initially tabulated in English units and a few analyses were carried out with English units. Table 14.1-1 contains conversion factors for converting from English to metric units. Conversion from metric to English units can be made by dividing by the factor or by multiplying by its reciprocal.

Table 14.1-2 presents additional conversion factors useful for interpretation of data reported herein.

14.2 Literature Cited

Table 14.2-1 is a bibliography of literature cited in the text. Reference in the text is by author and year.

TABLE 14.1-1

TABLE OF CONVERSION FACTORS

To Convert From	To	Multiply By
acres	ft^2	4.3560×10^4
acres	hectares	0.404687
atmospheres	dynes/cm^2	1.01325×10^6
atmospheres	bars	1.01325
atmospheres	mm H_g	760
atmospheres	newtons/m^2	1.01325×10^5
atmospheres	lbs/ft^2	2116.32
bars	atmospheres	0.98692
bars	mb	1000.00
bars	newtons/m^2	10^5
BTU (British Thermal Units)	gm. cal.	252.
cfm	liters/sec.	0.4720
cfs	gpm	448.831
cfs	m^3/s	0.028317
degrees Fahrenheit	degrees Kelvin	(°F-32)*(5/9)+273
degrees Fahrenheit	degrees Centigrade	(°F-32)*(5/9)
degrees	radians	0.017453
feet	meters	0.3048
ft^2	$meters^2$	0.092903
ft^3/min	m^3/sec.	0.000472
ft^3	gals	7.481
ft^3	m^3	0.028317
gals	m^3	0.0037854
gals	liters	3.7853
gals/min	m^3/sec.	0.00006309
gals/min	liters/sec.	0.069088
grains	grams	0.064798918
grains	pounds	1.42857×10^{-4}
hectares	m2	10^4
inches	cm	2.5400
$inch^3$	cm^3	16.3872
langleys	cal/cm2/min	1.000
miles	kilometers	1.60935
mph	mps	0.44703
pounds	kilograms	0.45359
pounds/acre	kg/ha	1.12173
pounds/acre	gms/m2	0.112173
pounds/hour	grams/sec.	0.1260
pounds/$inch^2$	atmospheres	0.068046
pounds/$inch^2$	mb	68.947
radians	degrees	57.29578
rods	meters	5.0292
SCFM (Standard Cubic Ft/Min)	ACFM (Actual cubic ft/min	$(^oK_a/^oK_s)(P_s \text{ mb}/P_a \text{ mb})$
ton (short)	kilograms	907.185

TABLE 14.1-2

ADDITIONAL CONVERSION FACTORS MULTIPLES AND SUBMULTIPLES OF UNITS

Factor by Which Unit is Multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	m
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

CONVERSION FACTORS FOR GASES

Molecular Weight (MW)	Pollutant	To Convert µg/m^3 at 25°C and 760 mmHg to ppb Multiply by Factor
46.01	NO_x as NO_2	.532
30.01	NO	.815
46.01	NO_2=NO_x -NO	.532
64.06	SO_2	.382
34.08	H_2S	.718
-	THC	1.530
16.01	CH_4	1.525
28.01	CO	.873
48.00	O_3	.510

Equation: $\frac{22.414}{MW} \left(\frac{298}{273}\right) = \text{Factor}$

TABLE 14.2-1

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